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IMPACT OF LOW ALTITUDE COVERAGE REQUIREMENTS ON AIR-GROUND COMMUNICATIONS

AMAF Industries, Inc.
103 Sterrett Building
Columbia, Maryland 21044

MARCH 31, 1981
FINAL REPORT

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A representative area of Appalachia surrounding Charleston, West Virginia is analyzed in terms of existing helicopter traffic patterns and communications facilities. Traffic patterns were established from telephone interviews with pilots flying this area regularly. Communications coverage was established from computer generated coverage contours obtained from the Electromagnetic Compatability Analysis Center (ECAC) and verified by pilot interviews and one flight test (as reported by the FAA Technical Center). Techniques for improving coverage are discussed. These include two new remote communication outlets located in the mountains west and south of Beckley, W.Va., a high gain antenna at Charleston pointed in a southerly direction, the use of mobile radio telephone to permit pilots to access nearby telephone facilities when on the ground at a remote site, short range less than 150 miles, hf radio, and a discrete frequency for exclusive use by low-flying aircraft.

FAA activities directed at improving communications to helicopter traffic flying to and from offshore oil and gas platforms in the Gulf of Mexico is presented in an Appendix.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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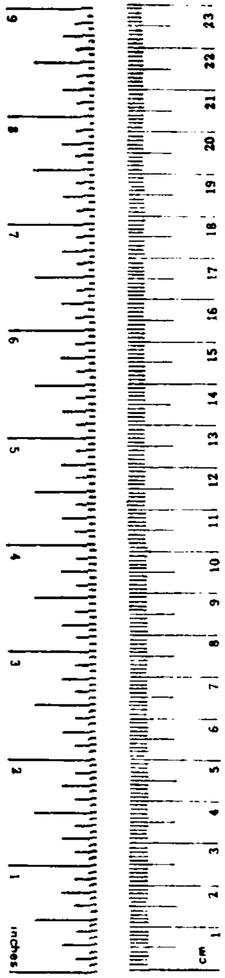
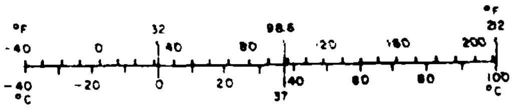
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This report discusses the air ground communications problems and possible solutions for low flying aircraft and helicopters in Appalachia. It also documents FAA activities directed at improving communications to heavy helicopter traffic flying to and from offshore oil and gas platforms in the Gulf of Mexico.

The major effort on this task was concentrated on Appalachia although a related problem exists in the Gulf of Mexico. The report describes the Southwest Regional plan for low altitude communications over the Gulf of Mexico as documented in appendix A. Implementation has already begun and if completed as planned will result in vastly improved communications to the low flying aircraft in this area.

A

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SECTION 1.0

SUMMARY

1.1 OVERVIEW OF PROBLEM AND CONSTRAINTS

A significant problem confronting the northeastern region in Appalachia is providing reliable communications to the rapidly increasing helicopter traffic flying to and from sites engaged in coal mining operations on the rugged terrain of the western slope of the Appalachian Mountains. The area of concern extends from Charleston, West Virginia to Bristol, Tennessee. The terrain is characterized bv high steep hills surrounded by deep, narrow valleys into which helicopters must frequently fly. The helicopter thus is often located in an airspace that is either completely shielded from all normal ground based FAA communications facilities, or if within range of a ground facility, may find that the facility is occupied with traffic generated by one or more high altitude aircraft which have line-of-sight access to many ground facilities. Communication with air traffic control, flight service stations, VOR/DME, terminal facilities, and towers is often marginal at best. At many unimproved sites where helicopters are required to land, the nearest telephone outlet may be located at a distance of several miles. Large gaps exist in low altitude communication coverage that could lead to hazardous flying conditions. Low flying aircraft and helicopters share the same airspace as low altitude VFR military training flights and they are often unaware of these flights because of the lack of communications.

While the problem exists throughout Appalachia, this report is restricted to a representative area surrounding Charleston, West Virginia which includes Charleston, Beckley, Rainelle, and Henderson. This area is considered typical of all Appalachia. Problems and solutions encountered therein should be directly applicable to similar problems encountered throughout the area of concern.

1.2 SUMMARY AND CONCLUSIONS

A representative area of Appalachia surrounding Charleston, West Virginia was analyzed in terms of existing helicopter traffic patterns and communications facilities. Traffic patterns were established from telephone interviews with pilots flying this area regularly. There did not appear to be a highly regulated and consistent set of flight paths due to the transient nature of the mining operations. Communications coverage was determined from computer generated coverage contours obtained from the Electromagnetic Compatability Analysis Center (ECAC) through the FAA Spectrum Management Branch. These data were confirmed by pilot interviews and the report of a single flight test previously conducted by the FAA Technical Center. Several possible methods for improving coverage in the area of study are evaluated. The changes include:

(a) Installation of two additional Remote Communication Outlets (RCO) located in the mountains approximately 10 miles west of Beckley, West Virginia and another 10 miles to the south at Flat Top Mountain. This option is considered less cost effective then option (b) following.

(b) Installation of a high gain, southward pointing, directional antenna at Charleston, West Virginia. This option is considered more cost effective than option (a).

An alternative to the use of conventional vhf radio is to utilize low power hf communications. The U.S. Army has considered this option for use with their operational helicopter forces which are freqently required to operate in difficult terrain. Implementation of hf radio will require the assignment of several frequencies in the overcrowded spectrum between 2 to 8 MHz. A study should be made to determine the availability of frequency assignments in this band before implementation.

Mobile radio telephone equipment should be installed at remote mine and construction sites to assist pilots in reaching nearby telephone facilities. This would allow filing of flight plans and checking on weather and overhead air traffic conditions. A discrete frequency should be assigned for exclusive use by low-flying aircraft and helicopters.

The agreement among the theoretical coverage contours, the limited flight test data, and results of pilot interviews lends confidence to use of computer-generated coverage plots as a useful communication planning aid.

SECTION 2.0

TRAFFIC AND COMMUNICATIONS

2.1 TRAFFIC AND COMMUNICATIONS COVERAGE

This subsection provides the results of a telephone questionnaire directed to 11 pilots typical of those flying regularly in this area. This number represents roughly one third of all helicopter pilots and helicopters based within the sample area as shown in table 1. The purpose of the questionnaire was to establish traffic patterns, helicopter concentration and areas of poor communication. The major concentration of helicopters is in Charleston (14) and Beckley (6); other helicopters are scattered throughout the area as shown in table 2-1.

The base locations of 31 helicopters and typical flight paths flown by the eleven sampled pilots are shown in figure 2-1 and the data indicates that there are no well defined corridors that pilots consistently fly. Their destination can be anywhere in the area and is primarily to unimproved mine or construction sites as well as major population centers. Flight altitudes range anywhere from 500 to 6000 feet above ground. In general, there is no formal corporate flight dispatcher assigned. Flights are made, weather permitting, at the request of company executives or other supervisory personnel. Each pilot interviewed maintains a personal log of all flights made. Just what constitutes a flight is, however, not as well defined as in the case of fixed wing aircraft. Some pilots indicated that they consider one flight to consist of a complete itinerary of landings provided the engine was not shut down at each en route landing.

Only a minimum number of flights carry cargo or spare parts. Most flights are for the purpose of transporting passengers to remote areas that are more easily accessed by helicopter than by road.

2.2 PILOT REPORTED COMMUNICATIONS COVERAGE

Most pilots interviewed recognize that communication to FAA facilities is poorest at the low altitudes south and southwest of Charleston, near Logan, and Williamson due to shielding by the terrain. It was very difficult, if not impossible, to obtain the exact boundaries of poor communications from pilot interviews, however, general locations were readily available.

Flight test measurements made in the FAA Convair-580 (N-49) confirmed the reported lack of communications.[1] Flight measurements showed that communications became unusable approximately 12 miles south of the Charleston airport at 1000 feet above the ground. This, however, represented only one point on the overall coverage contour. Theoretical computer-generated plots defining all points on the coverage contour

---

[1] Coyle, James, ANA-100D "Appalachian Region Air/Ground Communications Investigation" Trip Report, May 1980.

TABLE 2-1

HELICOPTERS BASED IN THE SAMPLE AREA

	Helicopters
Charleston	14
Beckley	6
Nitro	2
Barboursville	1
Beaver	1
Crab Orchard	1
Clay	1
Craigesville	1
Lewisberg	1
Gilbert	1
Logan	1
Mallory Airport	1
	31

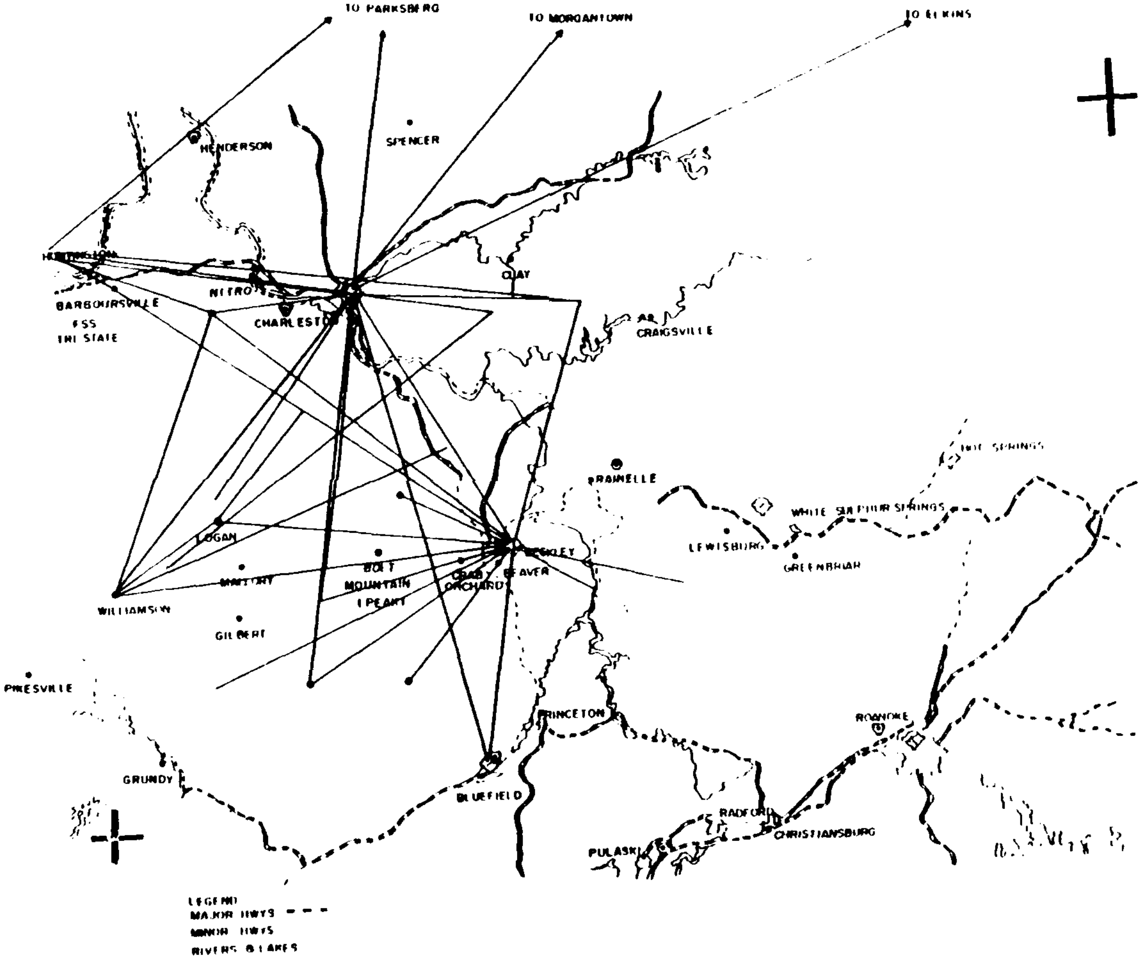

TO PARKSBURG
TO MORGANTOWN
TO ELKINS
HENDERSON
SPENCER
HUNTINGTON
NITRO
BARBOURSVILLE
FSS
TRI STATE
CHARLESTON
CLAY
CRAIGSVILLE
HOT SPRINGS
RAINELLE
WHITE SULPHUR SPRINGS
LEWISBURG
GREENBRIAR
LOGAN
BECKLEY
BOLT
MOUNTAIN
PEARL
CRAB ORCHARD
BEAVER
WILLIAMSON
GILBERT
PINESVILLE
PRINCETON
ROANOKE
GRUNDY
BLUEFIELD
RADFORD
CHRISTIANSBURG
PULASKI
LEGEND
MAJOR HWYS
MINOR HWYS
RIVERS & LAKES

FIGURE 2-1

TYPICAL FLIGHT PATHS OF
HELICOPTERS BASED IN REPRESENTATIVE AREA
CHARLESTON, RAINELLE, BECKLEY, HENDERSON
(FROM PILOT REPORTS)

have been prepared utilizing the facilities of the Electromagnetic Compatability Analysis Center (ECAC), Annapolis, Maryland, and are presented in figures 2 through 5 of the following section. The ECAC data agrees almost exactly with the single flight test at 1000 feet AGL. The agreement between theoretical contours and measurements lends confidence to the theoretical techniques as a powerful tool in communications planning.

SECTION 3.0

RADIO COVERAGE - EXISTING

3.1 RADIO COVERAGE FOR LOW-FLYING AIRCRAFT

This section provides the results of a theoretical investigation into the radio coverage provided by FAA facilities to low-flying aircraft in the representative area. The radio coverage contours produced by omnidirectional antennas located at Charleston, Beckley, Rainelle, and Henderson for aircraft at elevations of 10, 500, 1000, and 1500 feet above ground are shown in figures 3-1 through 3-4. The contours shown on these plots identify the approximate limits of radio coverage provided by the indicated FAA facilities to low-flying aircraft at elevation increments from ground level up to 1500 feet.

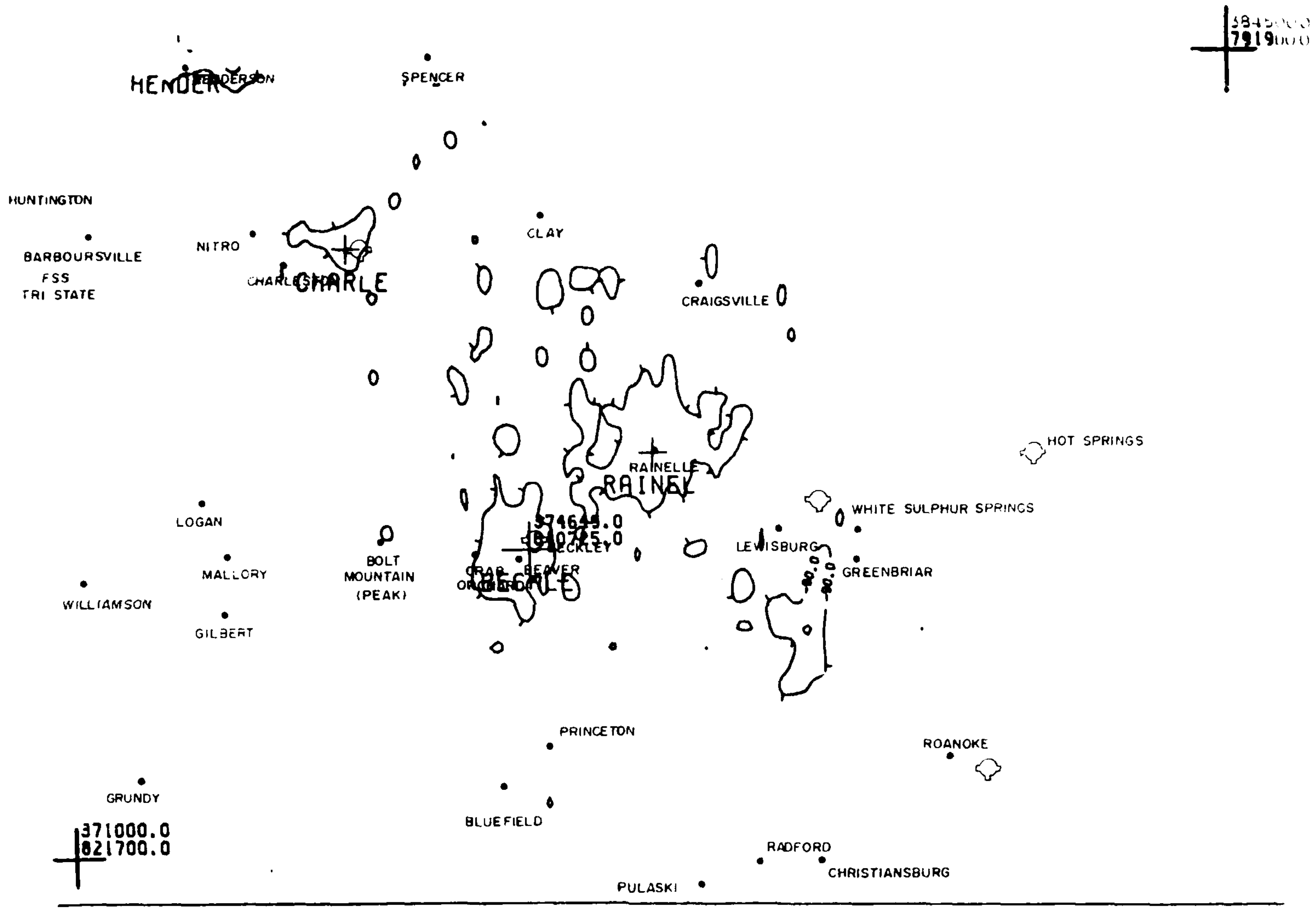
This sequence of plots identifies specific "holes" of missing communications coverage to the south and southwest of Charleston and verifies the flight test and pilot reports of poor, low-altitude communications capability in this area. Coverage gaps diminish in extent as the aircraft altitude increases, but they persist in the extreme southwest region around Logan, Williamson, and neighboring areas of Kentucky and Virginia. This coverage gap is due primarily to relatively high (to 3500 feet) intervening mountain ridges just west of Beckley in the Kopperston, Bolt area.

A mountain peak near Bolt, West Virginia is located on the coverage contours, where, on the ground elevation contour, figure 3-1, a small isolated area, on the northeasterly slope of the mountain is shown illuminated by radiowaves emanating from Beckley. Even at higher elevations, however, coverage does not extend very far beyond this point.

The computerized plots are comprehensive, covering the entire representative area. They were obtained from the ECAC's terrain database and computer programs which they have developed. Their program computes the power density in dbm/m^2 that would be obtained for aircraft at any point in the entire airspace above the representative area. The computer is also programmed to draw the contours of constant power density as has been illustrated in figures 3-1 through 3-4.

The power density contours take into account the terrain between the ground transmitter and the aircraft, the elevation above ground level of the aircraft, frequency, atmospheric and ground constants, but are independent of aircraft antenna and radio characteristics. Coverage contours are thus applicable approximately to those aircraft that meet FAA standards.[2] Aircraft that exceed standards may experience extended coverage, while aircraft whose receiving capability has deteriorated below standards may find their coverage restricted to regions smaller than that indicated.

[2] U.S. National Aviation Standard for VHF Air-Ground Communications System - FAA Order 6510.6, 11/11/77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BEAVER
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GILBERT
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PRINCETON
ROANOKE
GRUNDY
BLUEFIELD
371000.0
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RADFORD
CHRISTIANSBURG
PULASKI

FIGURE 3-1
RADIO COVERAGE CONTOUR PRODUCED BY OMNIDIRECTIONAL
ANTENNAS AT CHARLESTON, RAINELLE, BECKLEY AND HENDERSON
(a) 90 dbm/m^2 Contours
(b) 10 ft. AGL

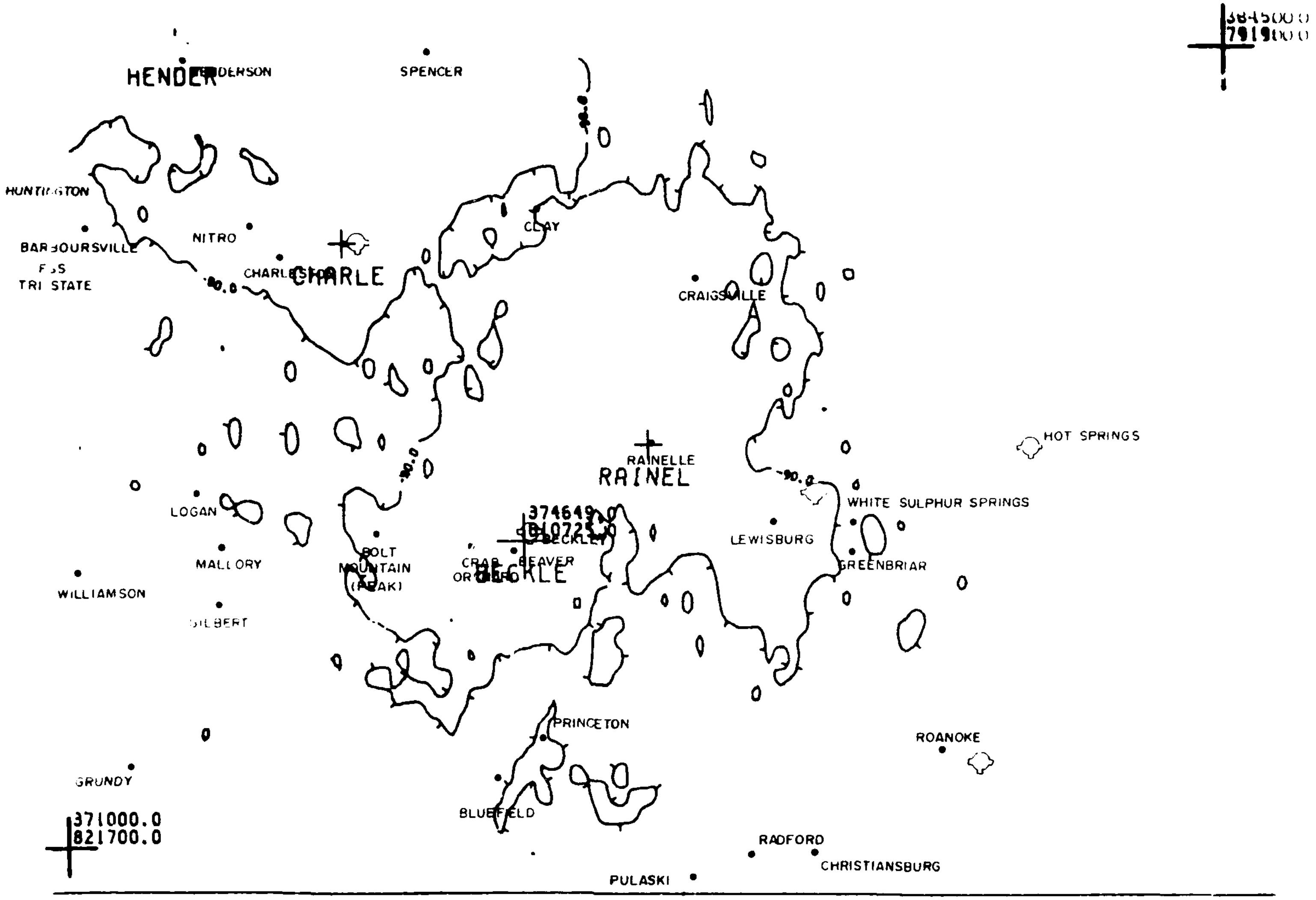
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FIGURE 3-2
RADIO COVERAGE CONTOUR PRODUCED BY OMNIDIRECTIONAL
ANTENNAS AT CHARLESTON, RAINELLE, BECKLEY AND HENDERSON
(a) 90 dbm/m^2 Contours
(b) 500 ft. AGL

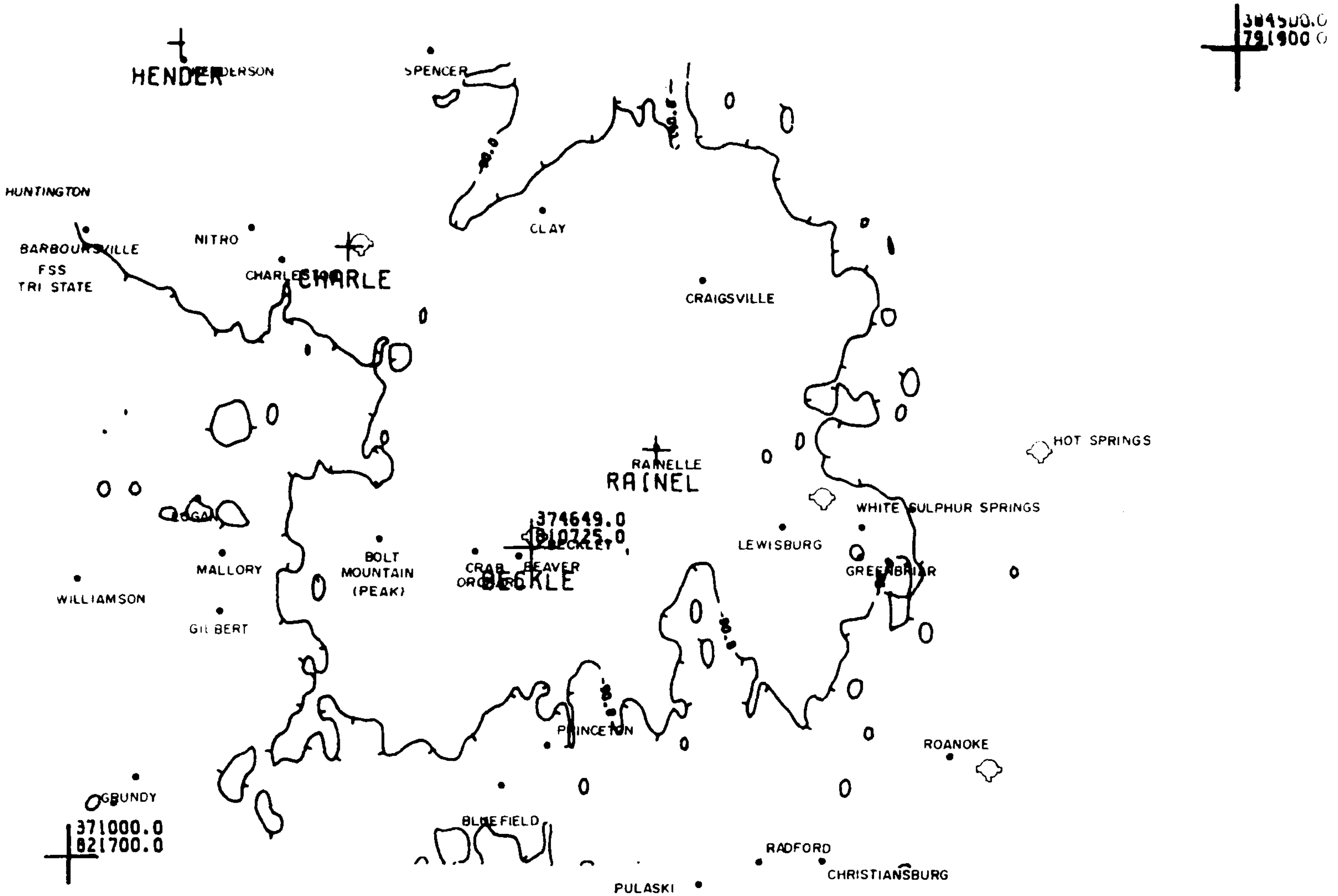
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FIGURE 3-3
RADIO COVERAGE CONTOUR PRODUCED BY OMNIDIRECTIONAL ANTENNAS AT CHARLESTON, RAINELLE, BECKLEY AND HENDERSON
(a) 90 dbm/m^2 Contours
(b) 1000 ft. AGL

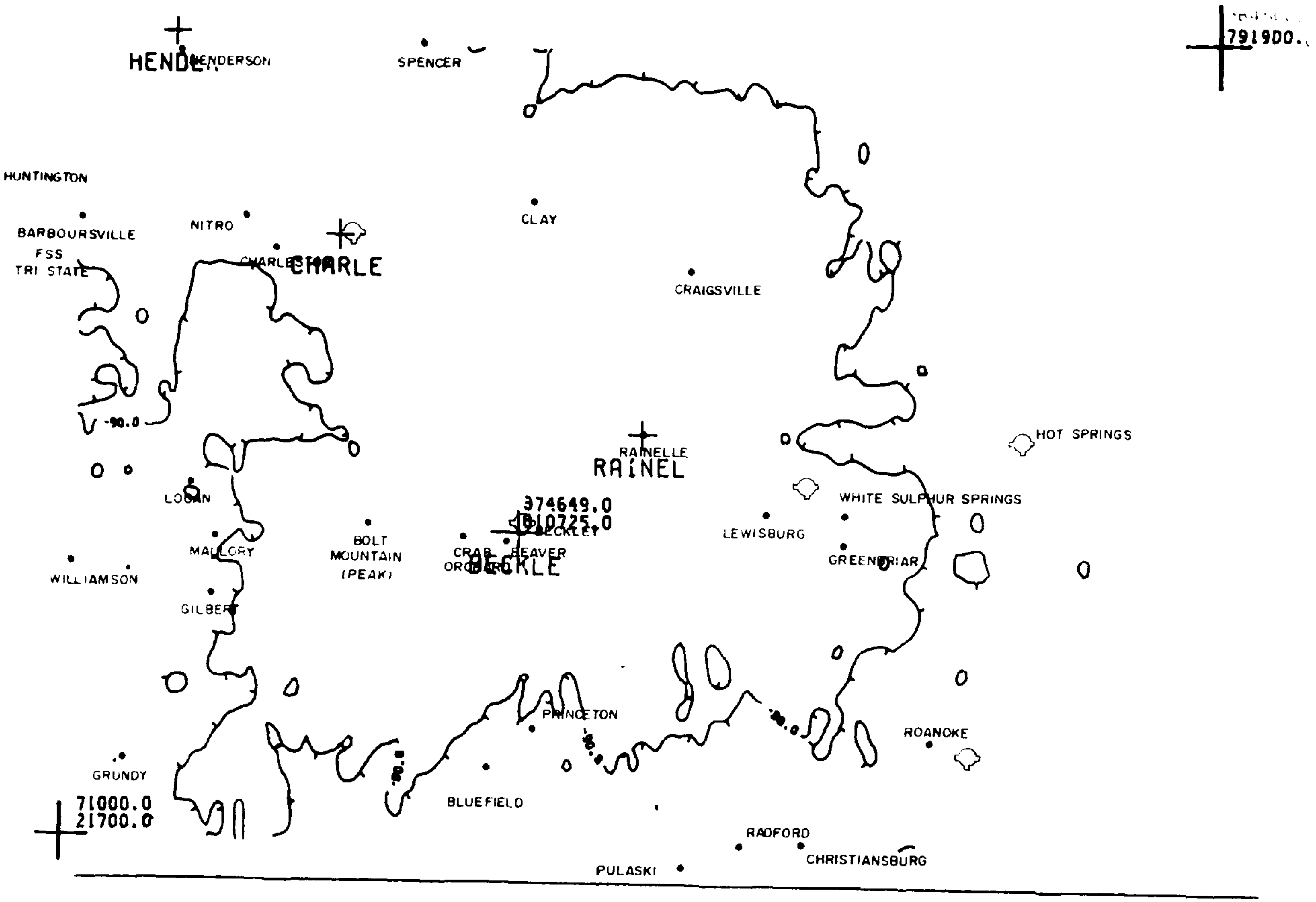
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FIGURE 3-4
RADIO COVERAGE CONTOUR PRODUCED BY OMNIDIRECTIONAL ANTENNAS AT CHARLESTON, RAINELLE, BECKLEY AND HENDERSON
(a) 90 dbm/m^2 Contours
(b) 1500 ft. AGL

Computer-generated radio coverage data in significantly more detail are provided by the power density plots presented in appendix C for those who may wish to determine the power density provided at any point in the three-dimensional space above the sample area from ground up to an elevation of 1500 feet AGL. These plots permit determination of power density contours other than the -90 dBm/m^2 discussed in this report. They may be used to determine the power density profile encountered by aircraft flying any arbitrary flight path including aircraft on the ground.

Coverage realized by a particular aircraft will be influenced largely by the VHF antenna used. In most cases the VHF antenna is mounted in front of the mast on top of the cabin. Other locations include the underside of the belly or boom. Omnidirectional patterns are desirable but very difficult to achieve in practice. Antenna patterns will vary from helicopter to helicopter. Nulls deeper than 10 db may be experienced in the horizontal pattern while 20-db variations are possible in zenith.

SECTION 4

IMPROVEMENTS - FUTURE

4.1 COMMUNICATIONS IMPROVEMENT RECOMMENDATIONS

This section addresses various changes that could be incorporated within the area analyzed to improve the capability to communicate with low-flying helicopters. The suggested changes are representative of those which could be evolved from a similar assessment of other areas of poor communication coverage in mountainous terrain. The recommendations, except for those related to hf radio installations are based on the premise that no large changes to the helicopter structure or antenna system would be acceptable to the many small operators involved.

4.2 IMPROVED RADIO COVERAGE

Computer-generated radio coverage plots of the previous section were used to reliably identify the coverage provided by existing facilities. Reliability of the theoretical technique was substantiated by comparing its predictions with results of a pilot's questionnaire and comparison with data gathered in an FAA Technical Center flight test. In this section we use the same techniques to predict the coverage that can be obtained from planned, hypothetical antenna facilities located at Charleston, Bolt Mountain, and Flat Top Mountain. Theoretical coverage contours resulting from the addition of radio facilities at these locations are illustrated in figures 4-1 through 4-12. Power density plots for each location are presented in appendix C.

The hypothetical improvement incorporated at Charleston consisted of installing a high-gain antenna pointing in a southerly direction. Results are shown in figures 4-1 through 4-4. The plots predict that, at 500 feet AGL and above, virtually all coverage gaps with the exception of those in the extreme west and in the area surrounding Williamson are filled. Additionally, at ground elevations, there are a number of high terrain areas that will permit direct communications to Charleston.

4.3 COMMUNICATIONS TO AIRCRAFT BELOW 500 FEET AGL

In spite of potential improvements in coverage for aircraft flying at 500 feet or above, the problem remains of providing communications to aircraft that are flying below 500 feet or that have landed in a valley. These aircraft are effectively shielded at vhf frequencies from all communications facilities. Establishing an RCO in each valley is not practical; however, several viable technical approaches appear to offer a feasible solution.

4.4 ADDITIONAL RCO'S

At least two areas have been identified where an additional RCO might prove of some benefit in improving communications to low-flying aircraft. These are Bolt Mountain about 10 miles west of Beckley (discussed previously) and Flat Top mountain, approximately the same distance to the south of Beckley near the West Virginia turnpike. Computerized radio coverage plots from omnidirectional antennas placed at both of these

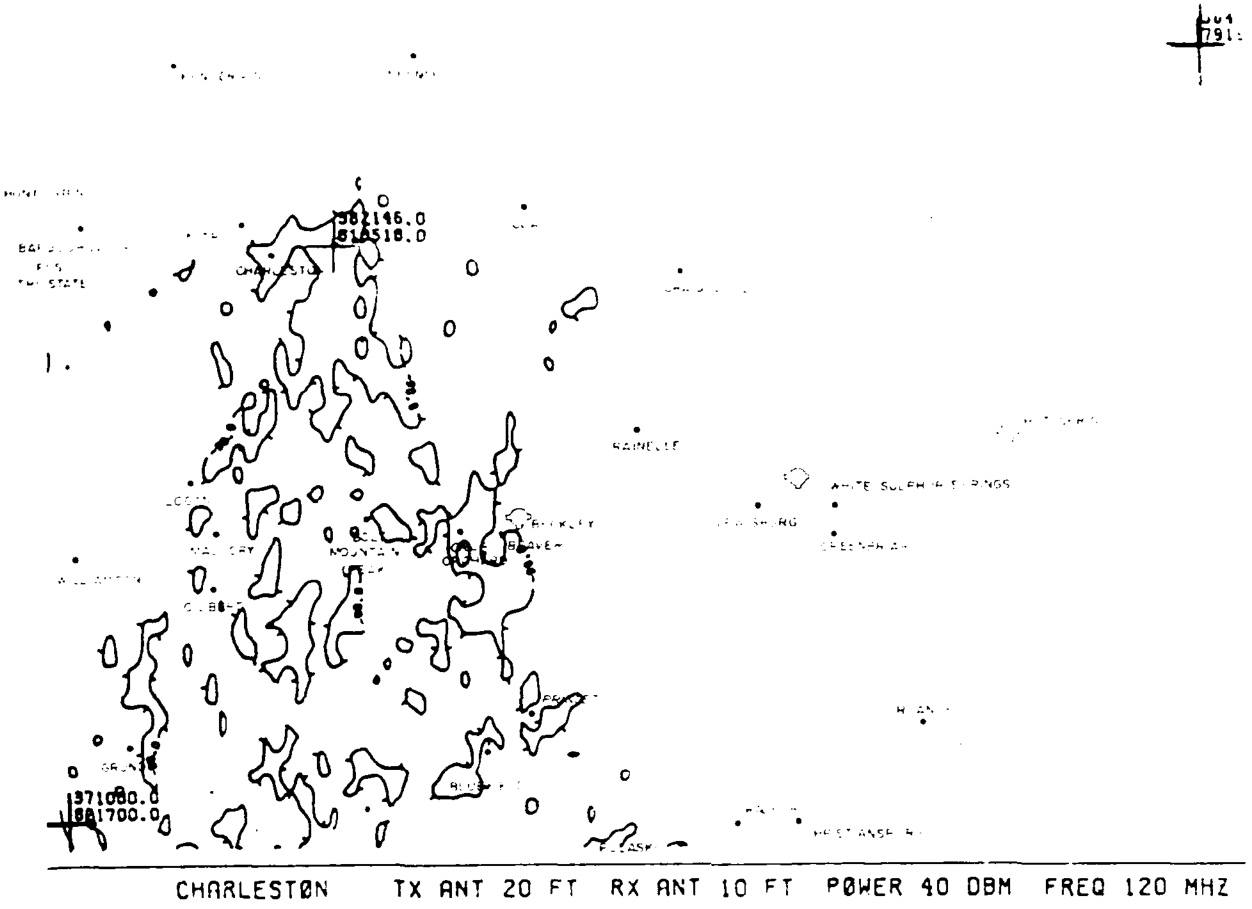

382146.0
816518.0
CHARLESTON
RAINELLE
WHITE SULPHUR SPRINGS
BECKLEY
BEAVER
MOUNTAIN
GILBERT
LOGAN
371000.0
881700.0
ASR
CHARLESTØN TX ANT 20 FT RX ANT 10 FT PØWER 40 DBM FREQ 120 MHZ

FIGURE 4-1

RADIO COVERAGE CONTOURS PRODUCED BY HIGH GAIN ANTENNA AT CHARLESTON, W.VA. POINT SOUTH
(a) 90 dbm/m^2 Contours
(b) 10 ft. AGL
(c) Antenna - TACO Y102B adjacent to new ASR tower elevation 65 ft.

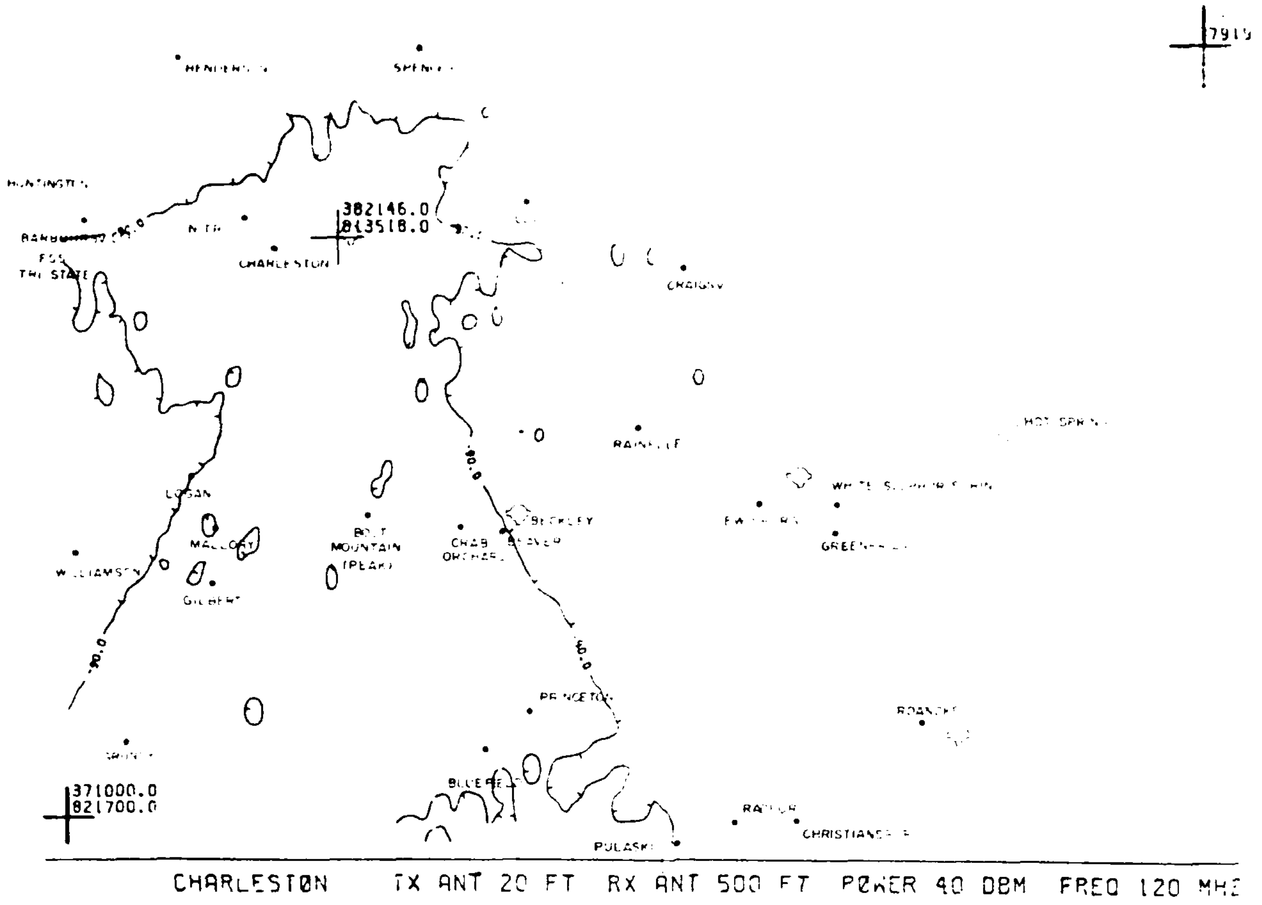

HENDERSON
SPENCER
HUNTINGTON
FSS
TRI STATE
NITRO
CHARLESTON
382146.0
813518.0
CRAIGSV
90.0
RAINELLE
HOT SPRINGS
WHITE SULPHUR SPRINGS
GREENBRIER
LOGAN
MALLORY
WILLIAMSON
GILBERT
BOLT
MOUNTAIN
(PEAK)
CRAB
ORCHARD
BECKLEY
BEAVER
PRINCETON
BLUEFIELD
PULASKI
RADFORD
CHRISTIANSBURG
ROANOKE
371000.0
821700.0
7915
CHARLESTON TX ANT 20 FT RX ANT 500 FT POWER 40 DBM FREQ 120 MHZ

FIGURE 4-2

RADIO COVERAGE CONTOURS PRODUCED BY HIGH GAIN ANTENNA AT CHARLESTON, W.VA. POINT SOUTH
(a) 90 dbm/m^2 Contours
(b) 500 ft. AGL
(c) Antenna - TACO Y102B adjacent to new ASR tower elevation 65 ft.

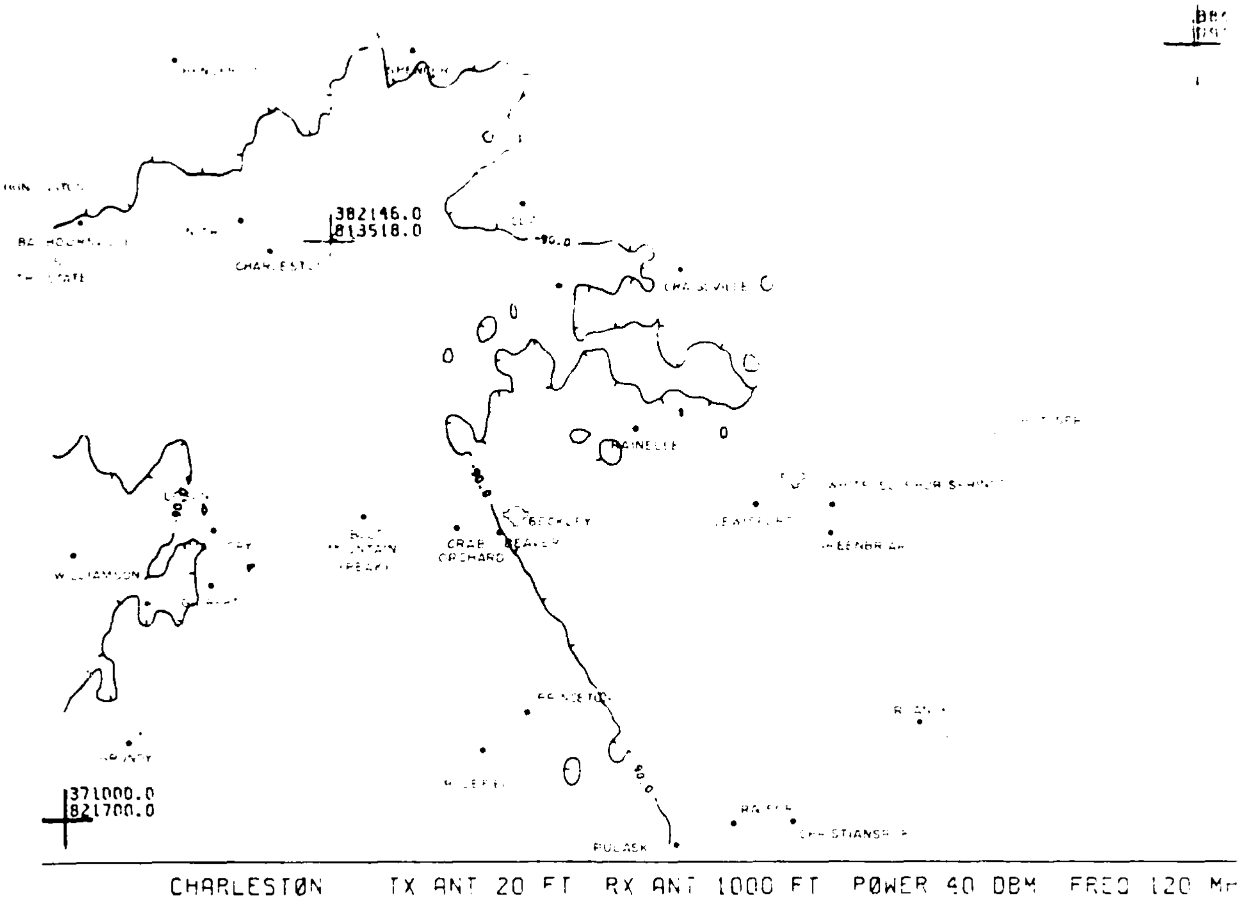

382146.0
813518.0
371000.0
821700.0
90.0
CHARLESTON
BECKLEY
BEAVER
CRAB ORCHARD
RAINELLE
WILLIAMSON
PULASKI
CHARLESTØN TX ANT 20 FT RX ANT 1000 FT PØWER 40 DBM FREQ 120 MH

FIGURE 4-3

RADIO COVERAGE CONTOURS PRODUCED BY HIGH GAIN ANTENNA AT CHARLESTON W.VA. POINTED SOUTH

(a) 90 dbm/m^2 Countours
(b) 1000 ft. AGL
(c) Antenna - TACO Y102B adjacent to new ASR tower elevation 65 ft.

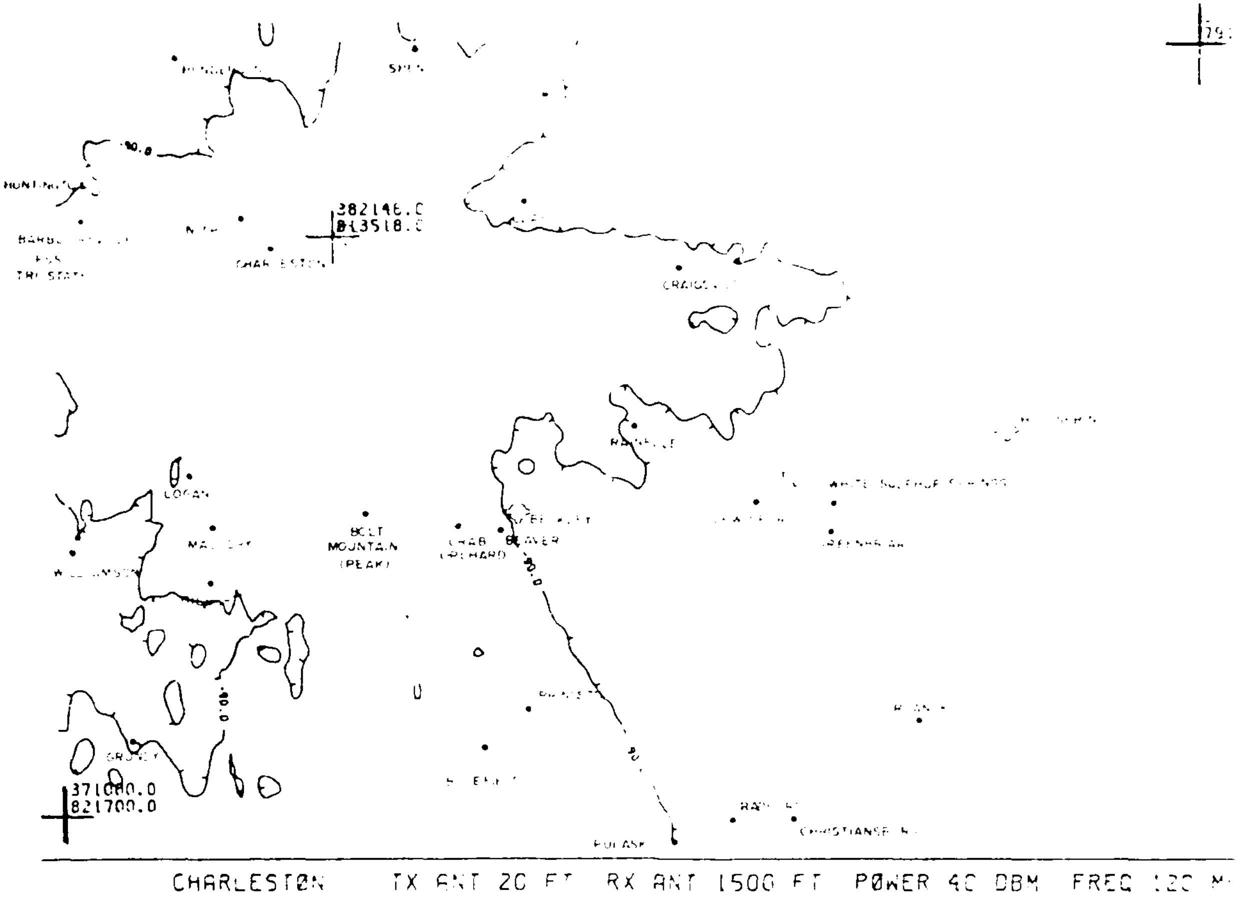
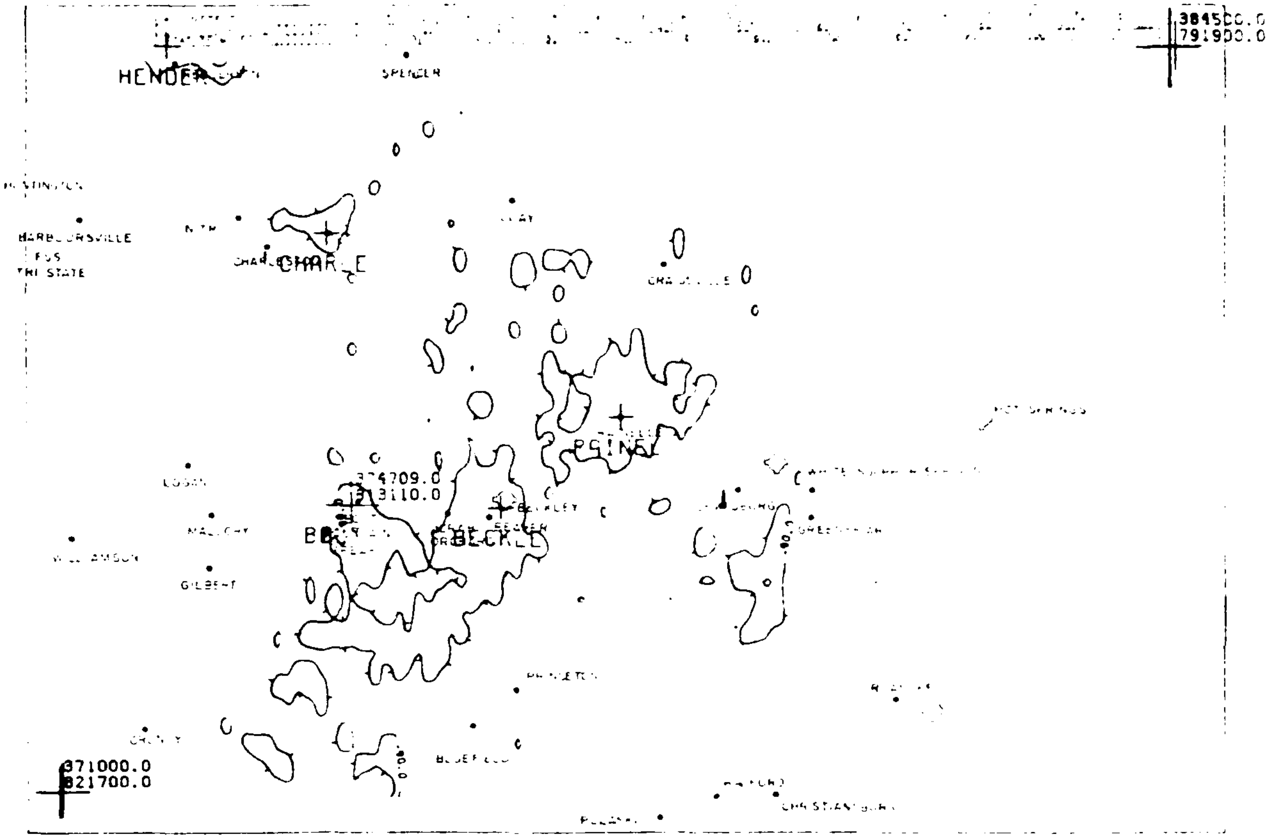

HUNTINGTON
BARBOURSVILLE
TRI STATE
CHARLESTON
382146.0
813518.0
SPENCER
CRAIGSVILLE
RAINELLE
WHITE SULPHUR SPRINGS
GREENBRIER
LOGAN
MADISON
WILLIAMSON
BELT MOUNTAIN (PEAK)
BECKLEY
BEAVER
90.0
GRUNDY
371000.0
821700.0
PULASKI
CHRISTIANSBURG
CHARLESTØN TX ANT 20 FT RX ANT 1500 FT PØWER 40 DBM FREQ 120 M

FIGURE 4-4

RADIO COVERAGE CONTOURS PRODUCED BY HIGH GAIN ANTENNA AT CHARLESTON, W.VA. POINT SOUTH

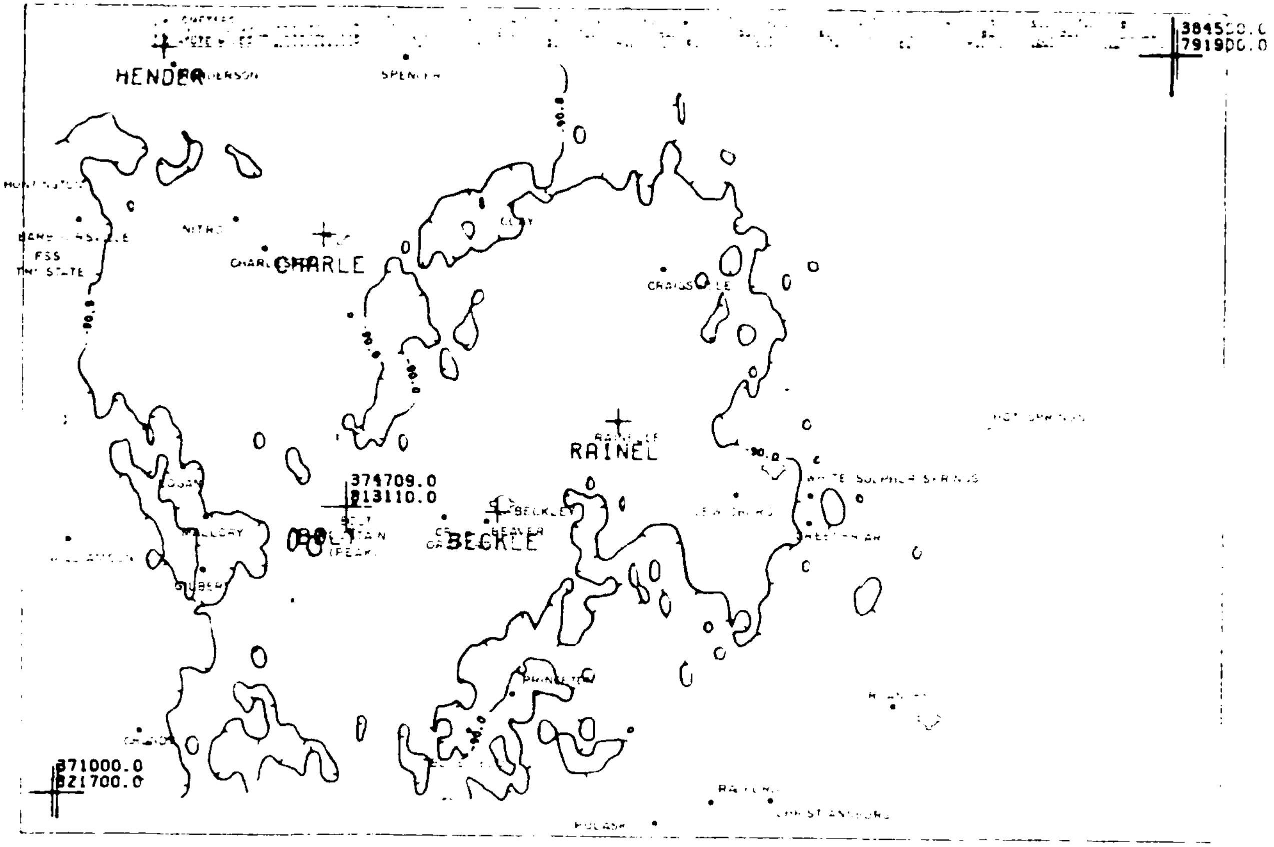
(a) 90 dmb/m^2 Contours
(b) 1500 ft. AGL
(c) Antenna - TACO Y102B adjacent to new ASR tower elevation 65 ft.


384500.0
791900.0
HENDER
SPENCER
BARBOURSVILLE
FOS
TRI STATE
CHARLE
374709.0
813110.0
BECKLE
GILBERT
-90.0
371000.0
821700.0

-90 DBM/M2 COMPOSITE OF CHARLESTON. RAINELLE. HENDERSON. BECKLEY AND BOLT
AT 10 FT

FIGURE 4-5

RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT BOLT MOUNTAIN
(a) 90 dbm/m^2 Contour
(b) 10 ft. AGL

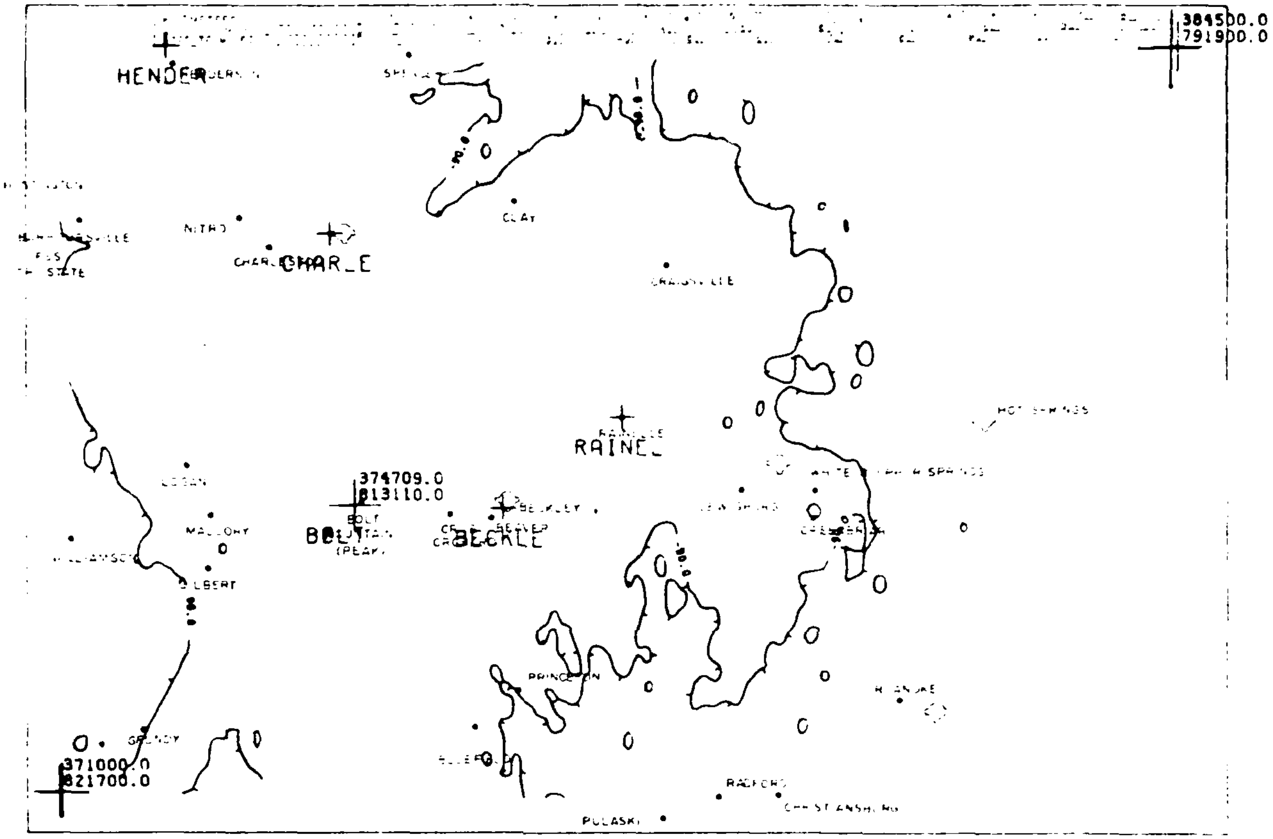


HENDER
HENDERSON
SPENCER
NITRO
CHARLE
CHARLESTON
CLAY
CRAIGSVILLE
RAINEL
RAINELLE
WHITE SULPHUR SPRINGS
BECKLE
BECKLEY
BEAVER
BOLT
PRINCETON
LOGAN
MALLORY
GILBERT
-90.0
374709.0
813110.0
371000.0
821700.0
791900.0

AT 500 FT
-90 DBM/M2 COMPOSITE OF CHARLESTON. RAINELLE. HENDERSON. BECKLEY AND BO

FIGURE 4-6

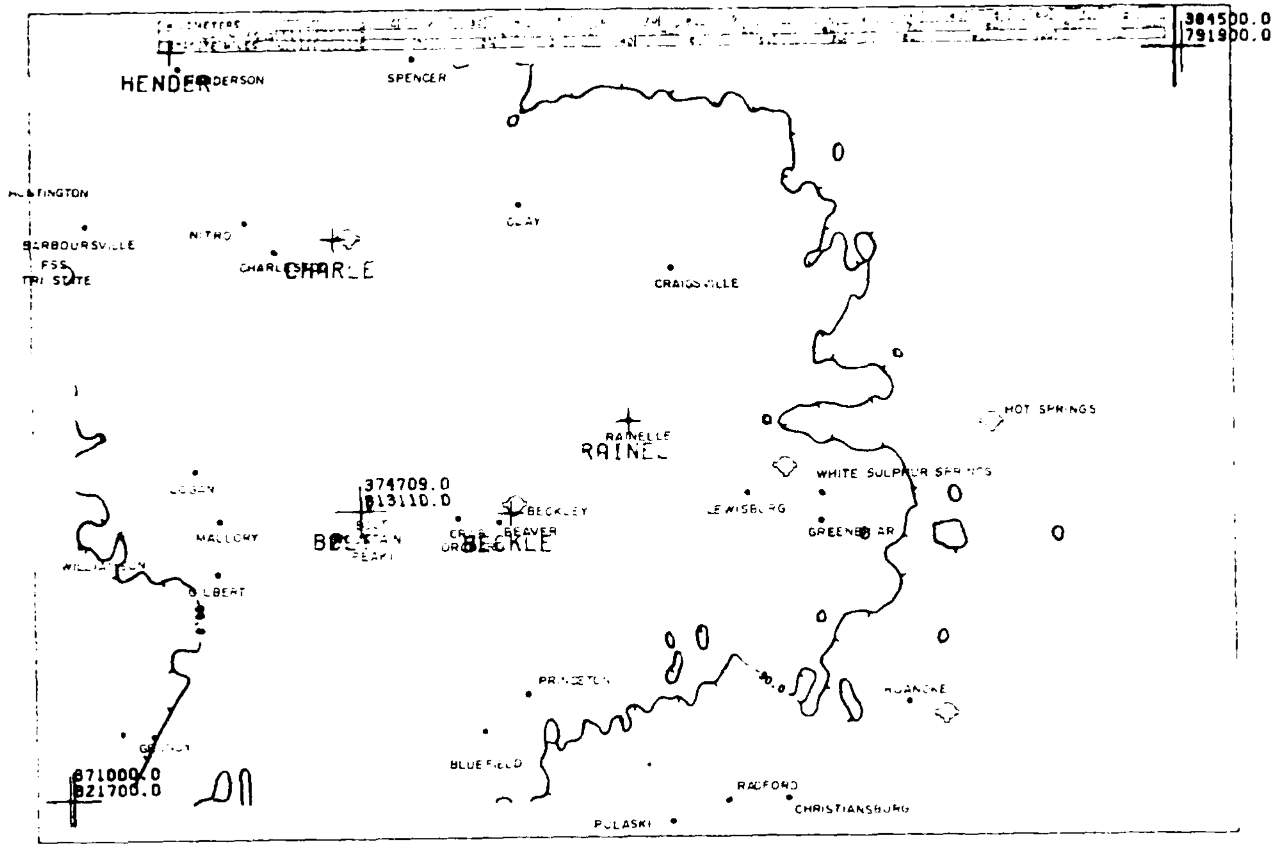
RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT BOLT MOUNTAIN
(a) 90 dbm/m^2 Contour
(b) 500 ft. AGL


384500.0
791900.0
HENDERSON
SPENCER
NITRO
CHARLESTON
CHARLE
CLAY
CRAIGSVILLE
-90.0
HOT SPRINGS
RAINELLE
RAINEL
WHITE SULPHUR SPRINGS
LOGAN
374709.0
813110.0
MALLORY
BOLT MOUNTAIN (PEAK)
BOLT
BECKLEY
BEAVER
BECKLE
LEWISBURG
GREENBRIER
GILBERT
PRINCETON
BLUEFIELD
GRUNDY
371000.0
821700.0
RADFORD
CHRISTIANSBURG
PULASKI

-90 DBM/M2 COMPOSITE OF CHARLESTON. RAINELLE. HENDERSON. BECKLEY AND BOLT AT 1000 FT

FIGURE 4-7

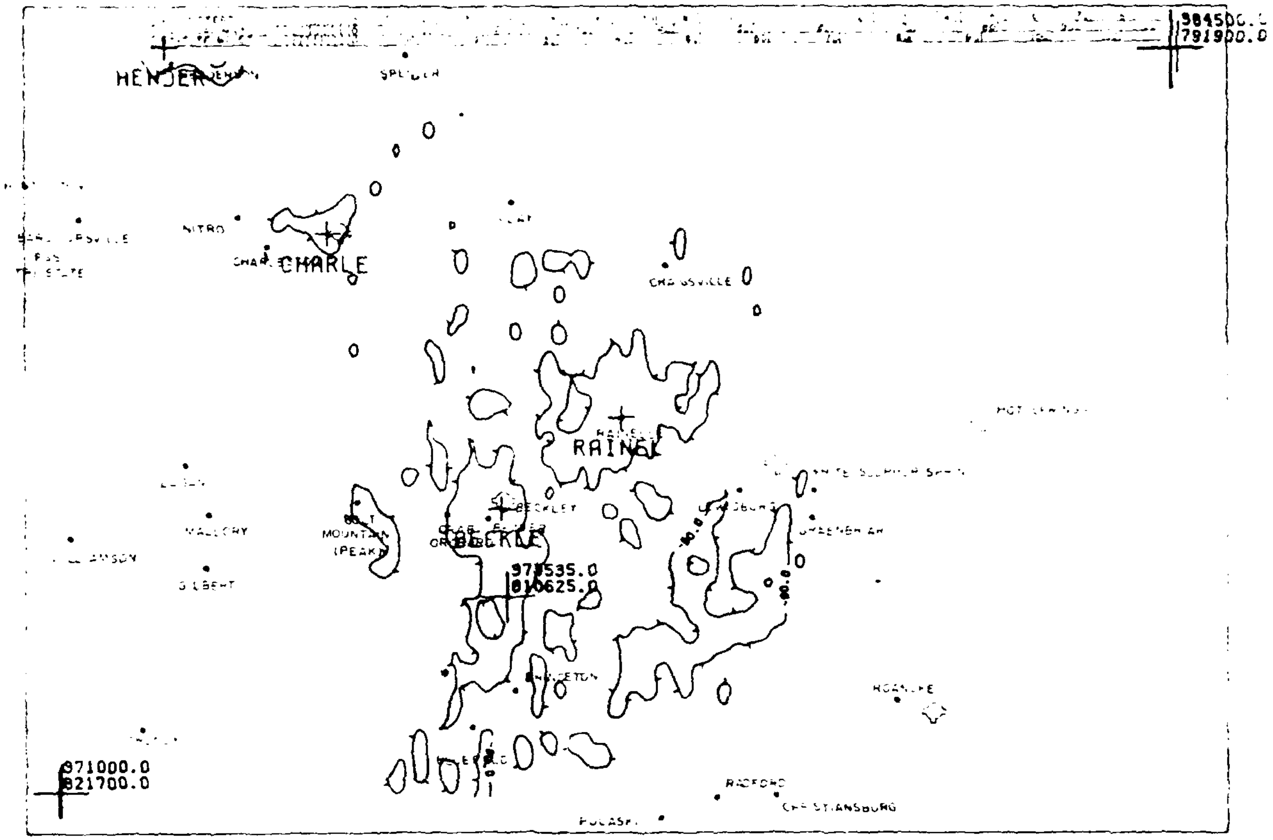
RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT BOLT MOUNTAIN
(a) 90 dbm/m^2 Contour
(b) 1000 ft. AGL


384500.0
791900.0
HENDER
HENDERSON
SPENCER
HUNTINGTON
BARBOURSVILLE
FSS
TRI STATE
NITRO
CHARLESTON
CHARLE
CLAY
CRAIGSVILLE
RAINELLE
RAINEL
HOT SPRINGS
WHITE SULPHUR SPRINGS
LEWISBURG
GREENBRIAR
LOGAN
MALLORY
374709.0
813110.0
BOLT
PEAK
BECKLEY
BEAVER
BECKLE
WILLIAMSON
GILBERT
PRINCETON
ROANOKE
BLUEFIELD
RADFORD
CHRISTIANSBURG
PULASKI
871000.0
821700.0

-90 DBM/M2 COMPOSITE OF CHARLESTON. RAINELLE. HENDERSON. BECKLEY AND BOL
AT 1500 FT

FIGURE 4-8

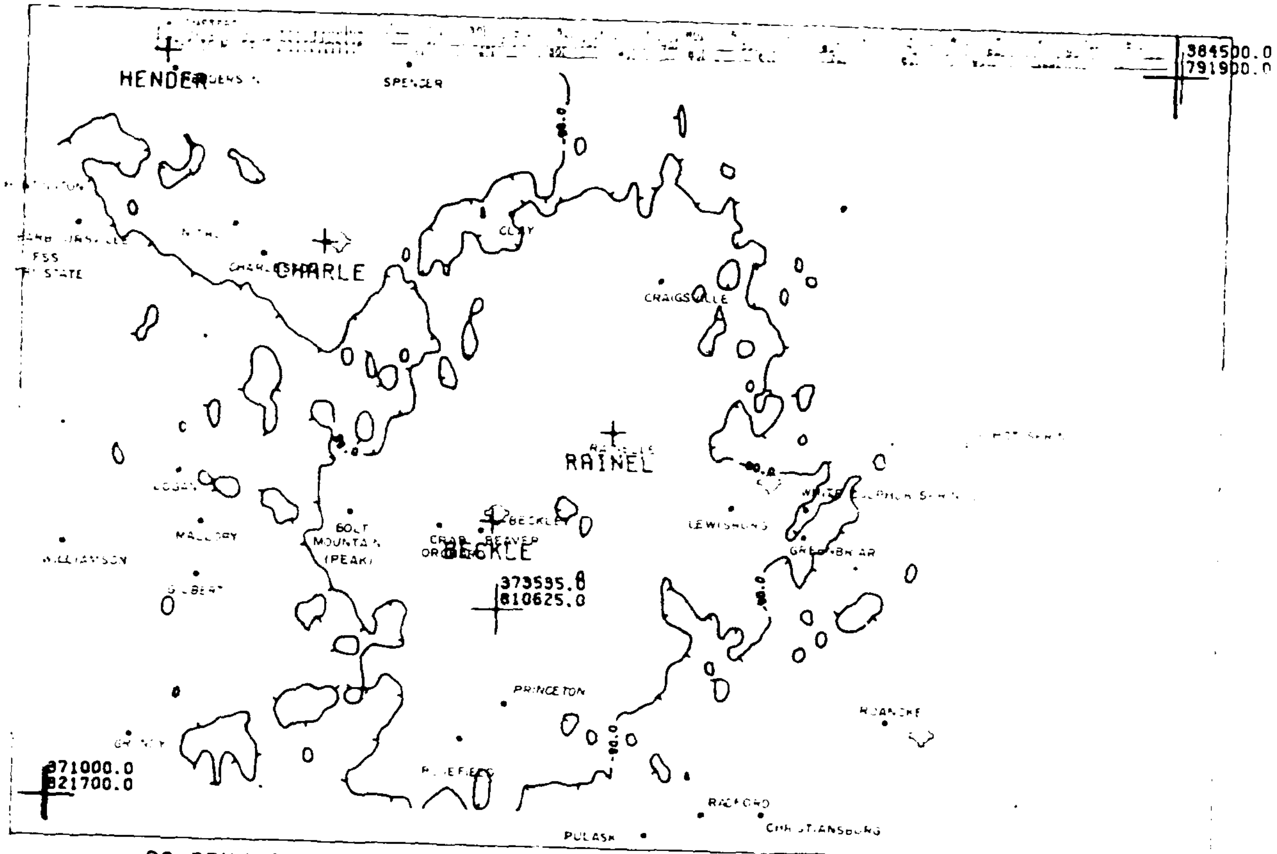
RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT BOLT MOUNTAIN
(a) 90 dbm/m^2 Contour
(b) 1500 ft. AGL


984500.0
791900.0
HENJER
NITRO
CHARLE
RAINEL
BECKLEY
BECKLE
MOUNTAIN
(PEAK)
979535.0
810625.0
971000.0
821700.0

-90 DBM/M2 COMPOSITE OF CHARLESTON. RAINELLE. HENDERSON. BECKLEY AND FLAT TOP MTN AT 10 FT

FIGURE 4-9

RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT FLAT TOP MOUNTAIN
(a) 90 dbm/m^2 Contour
(b) 10 ft. AGL

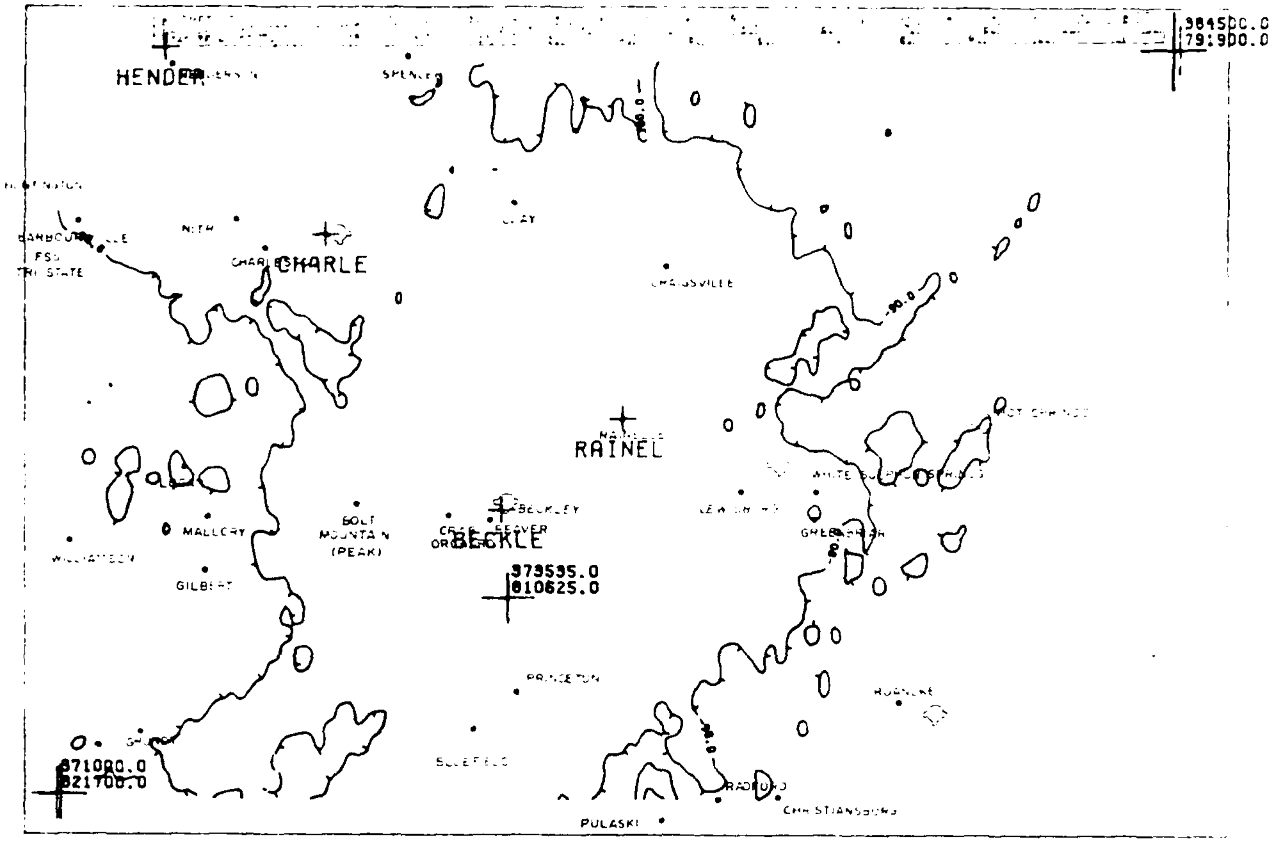


HENDER
SPENCER
CHARLE
CLAY
CRAIGSVILLE
RAINEL
BECKLE
BECKLEY
BEAVER
BOLT MOUNTAIN (PEAK)
MALLORY
WILLIAMSON
GILBERT
PRINCETON
LEWISBURG
GREENBRIAR
ROANOKE
RADFORD
CHRISTIANSBURG
PULASKI
FSS
TRI STATE
-90.0
384500.0
791900.0
373595.0
810625.0
371000.0
821700.0

-90 DBM/M2 COMPOSITE OF CHARLESTON, RAINELLE, HENDERSON, BECKLEY AND FLAT TOP MTN AT 500 FT

FIGURE 4-10

RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT FLAT TOP MOUNTAIN
(a) 90 dbm/m^2 Contour
(b) 500 ft. AGL



384500.0
79:900.0
HENDER
SPENCER
CLAY
CHARLE
CHARLESTON
NITRO
FSS
TRI STATE
CRAIGSVILLE
RAINEL
-90.0
HOT SPRINGS
WHITE SULPHUR SPRINGS
LEWISBURG
GREENBRIER
BECKLEY
BEAVER
BECKLE
CRAB ORCHARD
BOLT MOUNTAIN (PEAK)
MALLORY
GILBERT
WILLIAMSON
373535.0
810625.0
PRINCETON
BLUEFIELD
ROANOKE
RADFORD
CHRISTIANSBURG
PULASKI
371000.0
821700.0

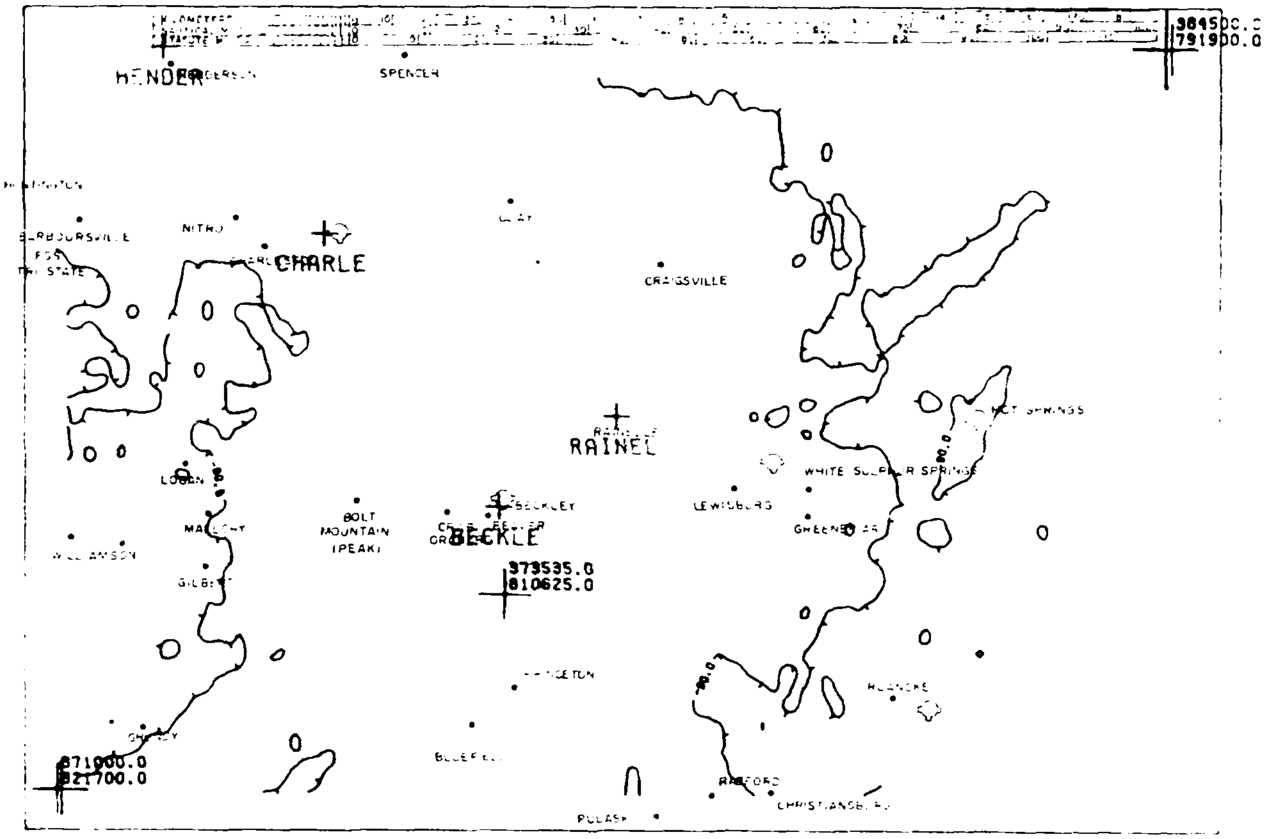
-90 DBM/M2 COMPOSITE OF CHARLESTON. RAINELLE. HENDERSON. BECKLEY AND FLAT TOP MTN AT 1000 FT

FIGURE 4-11

RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT FLAT TOP MOUNTAIN

(a) 90 dbm/m^2 Contour

(b) 1000 ft AGL


384500.0
791900.0
HENDER
SPENCER
HUNTINGTON
BARBOURSVILLE
FSS
TRI STATE
NITRO
CHARLE
CLAY
CRAIGSVILLE
RAINEL
HOT SPRINGS
WHITE SULPHUR SPRINGS
LEWISBURG
GREENBRIAR
LOGAN
MALLORY
WILLIAMSON
GILBERT
BOLT
MOUNTAIN
(PEAK)
BECKLEY
BECKLE
373535.0
810625.0
PRINCETON
BLUEFIELD
ROANOKE
RADFORD
CHRISTIANSBURG
PULASKI
371000.0
821700.0
-90.0

-90 DBM/M2 COMPOSITE OF CHARLESTON. RAINELLE. HENDERSON. BECKLEY AND FLAT TOP MTN AT 1500 FT

FIGURE 4-12

RADIO COVERAGE CONTOURS PRODUCED BY OMNIDIRECTIONAL ANTENNA AT FLAT TOP MOUNTAIN
(a) 90 dbm/m^2 Contour
(b) 1500 ft AGL

locations have been prepared to assist in making any site decisions and appear in figures 4-5 through 4-12. It appears from figures 3-1 through 3-4 that both these mountain ridges tend to limit coverage beyond them from FAA facilities at Beckley, Rainelle, and Charleston.

Coverage contours for Flat Top (figures 4-9 through 4-12) failed to show any significant improvement in radio coverage to the area southwest of Charleston, whereas, with the exceptionof the area surrounding Williamson, and RCO located at Bolt Mountain (figures 4-5 through 4-8) will provide significantly improved radio coverage to aircraft southwest of Charleston. These improvements, however, are not significantly better than those achieved by simply installing a high-gain antenna at Charleston (figures 4-1 through 4-4). The cost of installing a new RCO at Bolt as opposed to merely installing a high-gain antenna at Charleston appears to make this option not cost effective.

4.4.1 A DISCRETE FREQUENCY FOR LOW-FLYING HELICOPTERS

The difficulty experienced by low-altitude aircraft and helicopters in accessing the common receive-only facilities at the Flight Service Station outlets at Rainelle and Beckley may be considerably alleviated by the assignment of a discrete low-altitude frequency for their use.

4.4.2 VERTICAL POWER DENSITY FLIGHT PROFILES - CHARLESTON & BOLT

To further assess the radio coverage improvements provided by the high-gain antenna at Charleston and the installation of a new RCO at Bolt mountain, vertical power density flight profiles of a typical flight between Charleston and Logan at en route elevations of 1000 feet AGL and 3000 feet AGL are presented in figure 4-13 for conditions before improvements and after improvements. (Vertical power density profiles are obtained from the power density plots of appendix C; any arbitrary flight profile may be obtained in a similar manner).

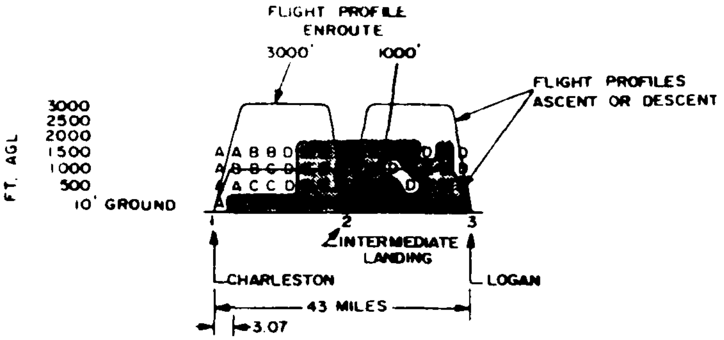
The shaded areas of figure 4-13 represent flight altitudes at which the signal at the aircraft is too weak to be usable by a standard radio receiver meeting FAA standards.[2]

The improvement in signal strength provided merely by the installation of a high-gain antenna at Charleston is apparent by the reduction of shadow area. For this particular flight, improvements provided by the Charleston high-gain antenna are greater than those provided by an RCO at Bolt Mountain. (Note that the vertical contours of figure 4-13 are for altitudes above ground level but do not indicate the actual profile of the ground between Charleston and Logan.

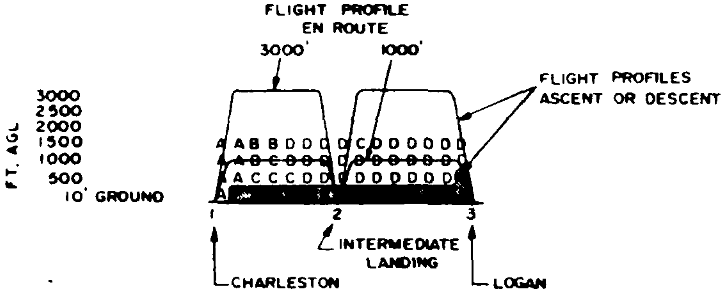
4.5 MOBILE RADIO TELEPHONE

Mine sites at which helicopters land may extend over a wide are, so that when a helicopter lands at an unimproved site, it may be at a distance of several miles from the location of the mine telephone installation. At minimal expense to the mine operators, a mobile radiotelephone system can be installed with a base station located where the telephone cable terminates. This would permit access to the telephone system by any

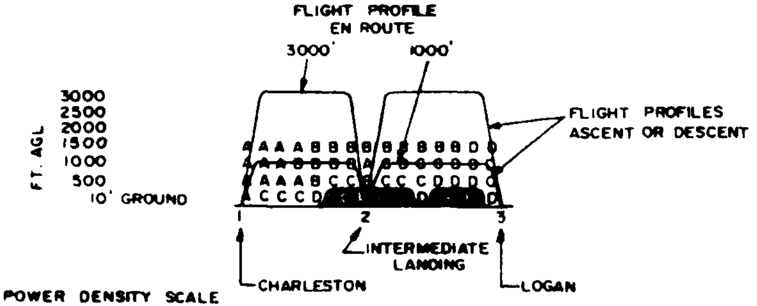
BEFORE IMPROVEMENTS


FLIGHT PROFILE
ENROUTE
3000'
1000'
FLIGHT PROFILES
ASCENT OR DESCENT
3000
2500
2000
1500
1000
500
10' GROUND
FT. AGL
A B B D
A B C D
A C C D
1
2
3
INTERMEDIATE LANDING
CHARLESTON
LOGAN
43 MILES
3.07

AFTER BOLT RCO INSTALLED


FLIGHT PROFILE
EN ROUTE
3000'
1000'
FLIGHT PROFILES
ASCENT OR DESCENT
3000
2500
2000
1500
1000
500
10' GROUND
FT. AGL
A AB B D D D D C D D D D D D
A C C C D D D D D D D D
1
2
3
INTERMEDIATE LANDING
CHARLESTON
LOGAN

AFTER CHARLESTON HIGH GAIN ANTENNA INSTALLED


FLIGHT PROFILE
EN ROUTE
3000'
1000'
FLIGHT PROFILES
ASCENT OR DESCENT
3000
2500
2000
1500
1000
500
10' GROUND
FT. AGL
A A A A B B B B B B B B B D D
A A A A B C C C C C C D D D D
C C C D
1
2
3
INTERMEDIATE LANDING
CHARLESTON
LOGAN

POWER DENSITY SCALE
IN dbm/m²

-50.000 >=	A >	-60.000
-60.000 >=	B >	-70.000
-70.000 >=	C >	-80.000
-80.000 >=	D >	-90.000
-90.000 >=	E >	-100.000
-100.000 >=	F >	-110.000
-110.000 >=	G >	-120.000
-120.000 >=	H >	-130.000
-130.000 >=	I >	-140.000

NOTE:
SHADED AREA REPRESENTS POWER DENSITIES LOWER THAN -90 dbm/m²

FIGURE 4-13. VERTICAL POWER DENSITY FLIGHT PATH PROFILES BEFORE AND AFTER COMMUNICATIONS IMPROVEMENTS

ground mobile units (including helicopters when on the ground and within several miles of a telephone termination) by means of a low-cost mobile terminal permitting them to dial directly into the telephone system from wherever they happen to be on the mine site. The helicopter pilot could then reach the appropriate air traffic control facility in order to file flight plans, check on weather conditions, and be alerted and receive notification of current or imminent activity on nearby low-level military training routes. Such equipment, FCC approved, is available today, off the shelf, at nominal cost. The approximate cost for a transmit/receive base station, hardwired into the telephone system, is about $5000. The approximate cost for the mobile transmit/receive unit varies from about $1800 to $2000. These costs seem small relative to the benefits of safety to pilots, passengers, and helicopter investment.

An alternative might be to clearly mark the telephone location so that it is visible from the air and ensure a clear area adjacent to the telephone facility for helicopters to land. In this way, pilots can make an intermediate short flight to the telephone prior to leaving the site.

4.6 HF COMMUNICATIONS - NEARLY VERTICAL INCIDENT SKY WAVE (NVIS)

Because of the near line-of-site limitations in the use of vhf communications, other users, including the U.S. Army, are looking into the use of the hf band for communications to aircraft on the ground or flying below 500 feet AGL.

The Army has investigated the use of short range hf using single hop skywave propagation also known as Nearly Vertical Incident Skywave Propagation (NVIS). It was found that a small segment of frequencies between 2 and 10 MHz will support reliable communications, regardless of the terrain or time of day.

The study addressed the band of frequencies which, when sent into the ionosphere at a nearly vertical angle, will be returned to the earth at a near point not to exceed about 150 miles in distance and with no skip zone characteristics. Because propagation is by skywave mode, the path loss for all cases is 120 db ±10 dB. Therefore, neither high-power nor highly efficient airborne hf antennas are required. In the absence of high ambient noise from electrical storms or traffic on the band, low-efficiency antennas such as 2 to 10 percent and an average power of 50 to 100 watts peak SSB is sufficient when operating over a frequency range of 2 to 10 MHz.

Effective radiation for short-range skywave propagation can be achieved by causing the excitation of the entire airframe. Tail whip, open and shorted transmission line antennas were evaluated. The shorted transmission line had superior gain characteristics in an azimuthal or horizontal aspect. The open transmission line was considered as the second best choice. The shorted transmission line had a gain of -18.6 dBd at 2 MHz to -5.2 dBd at 8.8 MHz for an average gain of -13 dBd.

Details of the hf tests are documented in report ECOM-4366.[3]

---

[3] Compact HF Antenna - Nov. 1975, Army Electronics Command, Fort Monmouth, New Jersey.

4.6.1 SUMMARY OF SIGNIFICANT ADVANTAGES OF NVIS

a. Path loss does not increase with ground range but is essentially constant at approximately 120 ±10 dB.

b. Because propagation is nearly vertical at all times, there is no terrain shadowing that is characteristic of satellite systems which require a low angle of incidence depending upon the position of the satellite in geostationary orbit. As an example, strong NVIS signals may be received in narrow valleys where satellite signals would not be available.

c. The coverage contour is terrain independent and will appear circular whether over the ocean or in rugged terrain such as West Virginia.

d. Signal-to-noise computations show that transmitter power requirements are modest, perhaps 50 to 100 watts.

e. Low-efficiency antennas in which the airframe becomes part of the antenna can be used.

4.6.2 SUMMARY OF DISADVANTAGES OF NVIS

a. Several frequency assignments in the band from 2 to 10 MHz must be available.

b. Optimum transmission frequencies must be continuously predicted or established via test circuits.

c. At present, radio equipment is very expensive -- on the order of $30,000 per aircraft.

d. Antenna exciters approximately 10 feet long must be installed along the side of the aircraft.

4.6.3 THEORY OF NEARLY VERTICAL SKYWAVE PROPAGATION

It has been known since the days of Marconi that radio signals in the 2 to 10 MHz band, when launched vertically, are returned to earth via reflection from the ionosphere. The big economic payoff in the early days was long distance communications via ionospheric refraction. The use of hf radio for short-range communication via nearly vertical skywave was largely neglected. The physics of skywaves that are vertically incident on the ionosphere is well understood. The hf propagation theory presented in the following paragraphs places emphasis on the physics of short range, nearly vertical incident skywave, as opposed to traditional treatment which places the emphasis on extremely long range propagation.

4.6.4 THE IONOSPHERE[4]

Ultraviolet light and a corpuscular form of ionizing radiation originating in the sun ionize the outer portions of the earth's atmosphere. This ionized region, or ionosphere, consists of free electrons, positive ions, and negative ions in a rarefied gas. The ionosphere will bend (refract) radio waves entering it as though it had a lower refractive index than air, or a refractive index between zero and one.

The amount of bending experienced by a wave incident upon the ionosphere at a given angle depends upon the effective refractive index of the ionized medium. The refractive index depends primarily on the electron density and frequency of the incident wave.

If we assume that there is very little change of electron density in the space of one wavelength, the refractive index may be written as:

$$\mu = \sqrt{1 - \frac{81N}{f^2}} \qquad (1)$$

where:

μ = refractive index = $\sqrt{\text{dielectric constant}} < 1$
N = electron density in electrons per cubic centimeter
f = frequency in kHz

Equation 1 shows that the refractive index is lower, the higher the electron density and the lower the frequency.

According to Snells law, the angle of refraction is given by:

$$\mu = \frac{\sin \phi_0}{\sin \phi} \qquad (2)$$

where:

ϕ_0 = angle of incidence of wave entering ionosphere
ϕ = angle of refraction
μ = refractive index

4.6.5 VERTICAL INCIDENCE REFRACTION - CRITICAL FREQUENCY

It follows from equation 2 that a wave striking the ionosphere with vertical incidence ($\phi_0 = 0^0$) will be returned to earth when the refractive index is reduced to zero because $\phi = 90^0$ (the condition for total reflection). Under this condition, the relation between electron density N and frequency f corresponding to $\mu = 0$ is from equation 1

$$f_v = \sqrt{81N} \qquad (3)$$

[4] Radio Engineering - Frederic Emmons Terman - McGraw Hill Book Company, 1950

or the required electron density is:

$$N \doteq \frac{f_v^2}{81} \qquad (4)$$

As the frequency of a wave returned by the ionosphere at vertical incidence is increased, the required electron density increases as shown by equation 4, and the wave penetrates farther into the ionosphere until the maximum electron density of the layer is reached. If the frequency is increased still further, the wave passes through the layer because the electron density is not sufficient to return the wave. The frequency at which the wave just barely penetrates the layer at vertical incidence is called the critical frequency and, in this case, is commonly used as a measure of the maximum electron density in the layer.

$$f_c = f_v\text{-max} = \sqrt{81N \text{ max}} = \text{critical frequency} \qquad (5)$$

Equations 1 and 2 may be rewritten:

$$\mu = \sqrt{1 - \frac{81N}{f^2}} = \frac{\sin \phi_0}{\sin \phi} \qquad (6)$$

when there is total reflection from the ionosphere at any angle of incidence $\phi = 90^0$ and

$$\mu = \sqrt{1 - \frac{81N}{f^2}} = \sin \phi_0 \qquad (7)$$

solving for f

$$f = \frac{\sqrt{81N}}{\sqrt{1 - \sin^2 \phi_0}} = \sqrt{81N} \sec \phi_0 \qquad (8)$$

Equation 8 shows that, at vertical incidence when $\phi_0 = 0$ and $\sec \phi_0 = 1$, the maximum frequency returned to earth is the critical frequency $f_c = \sqrt{81N}$, but as the angle of incidence deviates slightly from vertical, required by NVIS, ϕ_0 begins to increase slightly above zero and $\sec \phi_0$ increases slightly above unity so that frequencies greater than the critical frequency will be returned to earth.

4.6.6 VIRTUAL HEIGHT

One of the most important quantities in skywave transmission is the effective or virtual height. Referring to figure 4-14, this is the height of a hypothetical reflecting surface in free space for which the travel time of the wave is equal to the travel time of the wave in the actual ionized medium. In the case of vertical incidence transmission, the virtual height is the distance obtained by multiplying the velocity of light by one-half the time required for a pulse of radio energy to travel up to the ionosphere and back.

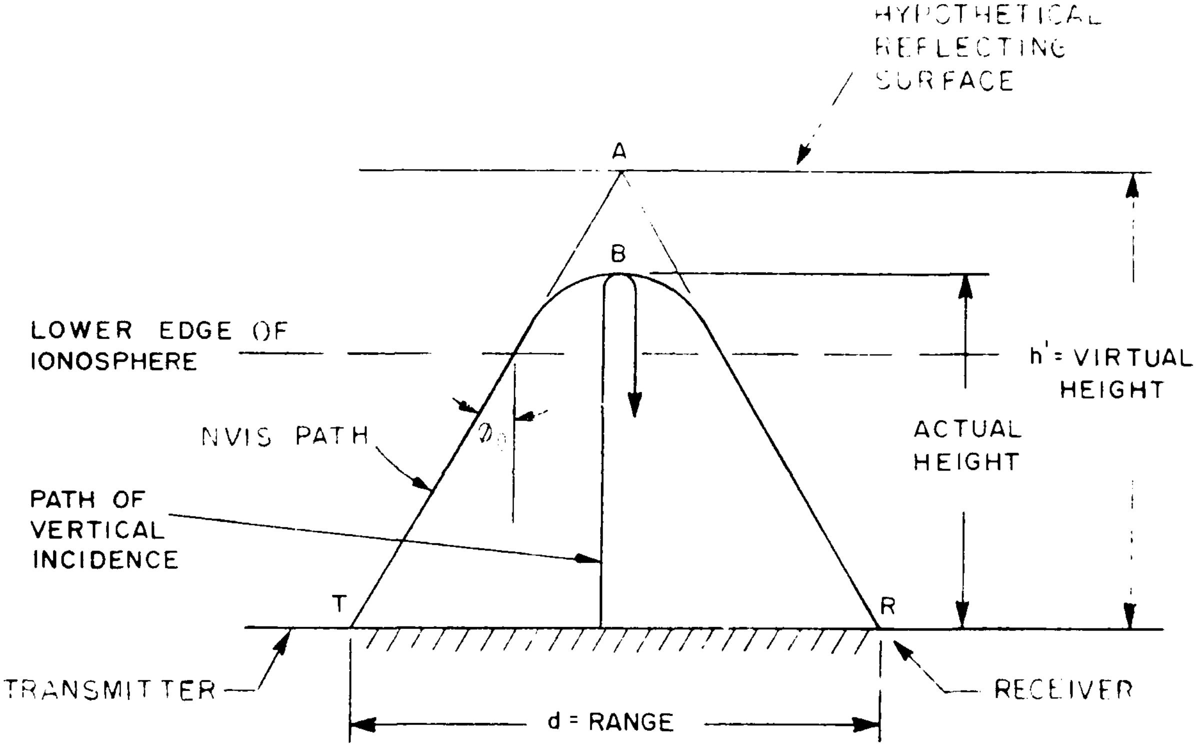

HYPOTHETICAL
REFLECTING
SURFACE
A
B
LOWER EDGE OF
IONOSPHERE
h' = VIRTUAL
HEIGHT
ACTUAL
HEIGHT
NVIS PATH
ϕ_0
PATH OF
VERTICAL
INCIDENCE
T
R
TRANSMITTER
RECEIVER
d = RANGE

FIGURE 4-14. GEOMETRY FOR VERTICAL AND NEARLY VERTICAL INCIDENCE ILLUSTRATING VIRTUAL HEIGHT - (PLANE IONOSPHERE, CURVATURE OF EARTH NEGLECTED)

It may be shown, in the case of a plane ionosphere, that the virtual height as defined above is the same as the height of the triangle formed by extending the straight line portions of the NVIS wave path. Referring to figure 4-14, this means that the time required for the wave to travel over the actual path TBR is the same as the time required for the wave to travel over the path TAR with the velocity of light. This relationship may be used to calculate the time required for a wave to travel from the transmitter to receiver.

For short ranges such that the curvature of the earth may be neglected, the geometry of figure 4-14 shows that

$$\tan^2 \phi_0 = \frac{d/2}{h'}^{\,2} \qquad (9)$$

by triginometric identity

$$\sec \phi_0 \equiv \sqrt{1 + \tan^2 \phi_0} = \sqrt{1 + \left(\frac{d/2}{h'}\right)} \qquad (10)$$

therefore from equation 8

$$\frac{f}{\sqrt{81N}} = \sqrt{1 + \left(\frac{d/2}{h'}\right)^2} \qquad (11)$$

where

h' is the virtual height

d is the range between receiver and transmitter

f = the frequency

N = electron density

In the case of a plane ionosphere (e.g., range is short enough so that the earth curvature may be neglected) the distance traveled by the NVIS as a function of ground range and can be computed from figure 4-14 to be

$$D = \frac{2\,h'}{\cos\left(\tan^{-1} \frac{d/2}{h'}\right)} \qquad (12)$$

where

D = distance traveled by NVIS

h' = virtual height

d = ground distance between transmitter and receiver

Thus for short ranges, say when

$$0 < d < h', \; h' \cong 300\text{km} = 186 \text{ mi}$$

then from equation (12)

$$(2h') < D < 1.12\,(2h')$$

Indicating that there is only a 12 percent change in the distance traveled by the NVIS wave when the ground path is increased from 0 to about 186 miles. This corresponds to approximately 1 db change in path loss. Therefore, for all practical purposes, the path loss via NVIS may be considered constant for short ground ranges up to about 186 miles.

4.6.7 THE FREQUENCY OF OPTIMUM TRANSMISSION (FOT)

As described earlier for vertically incident waves, a critical frequency exists above which all radiation penetrates the ionosphere and is lost in space. As the incident ray is lowered from vertical, less bending is required to return the wave to earth; thus, frequencies higher than the critical frequency can be used (demonstrated by equation 8). For long distance propagation, a term called the MUF (maximum usable frequency) is used to identify the highest frequency that will be returned to earth at very long ranges. The MUF is generally several times greater than the critical frequency ($\emptyset_0$ approaches 90^0 and sec $\emptyset_0$ gets large in equation 8). In the case of NVIS, however, because propagation is always nearly vertical, the MUF approaches the critical frequency and is only slightly larger than it.

Loss of energy from the wave as it enters the ionosphere can be attributed to two phenomena; absorption, due to setting ions in motion, which is greater at lower frequencies, and loss due to energy passing through the ionosphere as the frequency increases and approaches the MUF (a little greater than the critical frequency).

Thus, in vertical skywave propagation there exists a compromise; the frequency used for transmission must always be lower than the MUF yet not be so low as to be absorbed by the ionosphere. A frequency window may be thought to exist which contains a frequency of maximum reliability. This frequency is called the FOT (Frequency of Optimum Transmission).

As described earlier, the electron density of the ionosphere is caused by radiation from the sun, and therefore, there will be a diurnal variation of the FOT. A typical plot showing the daily variation in the FOT is illustrated in figure 4-15.

Computerized techniques exist for predicting the FOT and MUF. Printouts, a sample of which is shown in table 4-1, were obtained by users from the Propagation Agency, U.S. Army, Fort Huachuca, Arizona, for particular NVIS propagation paths. The propagation window can thus be predicted ahead as much as 6 months with reasonable accuracy.

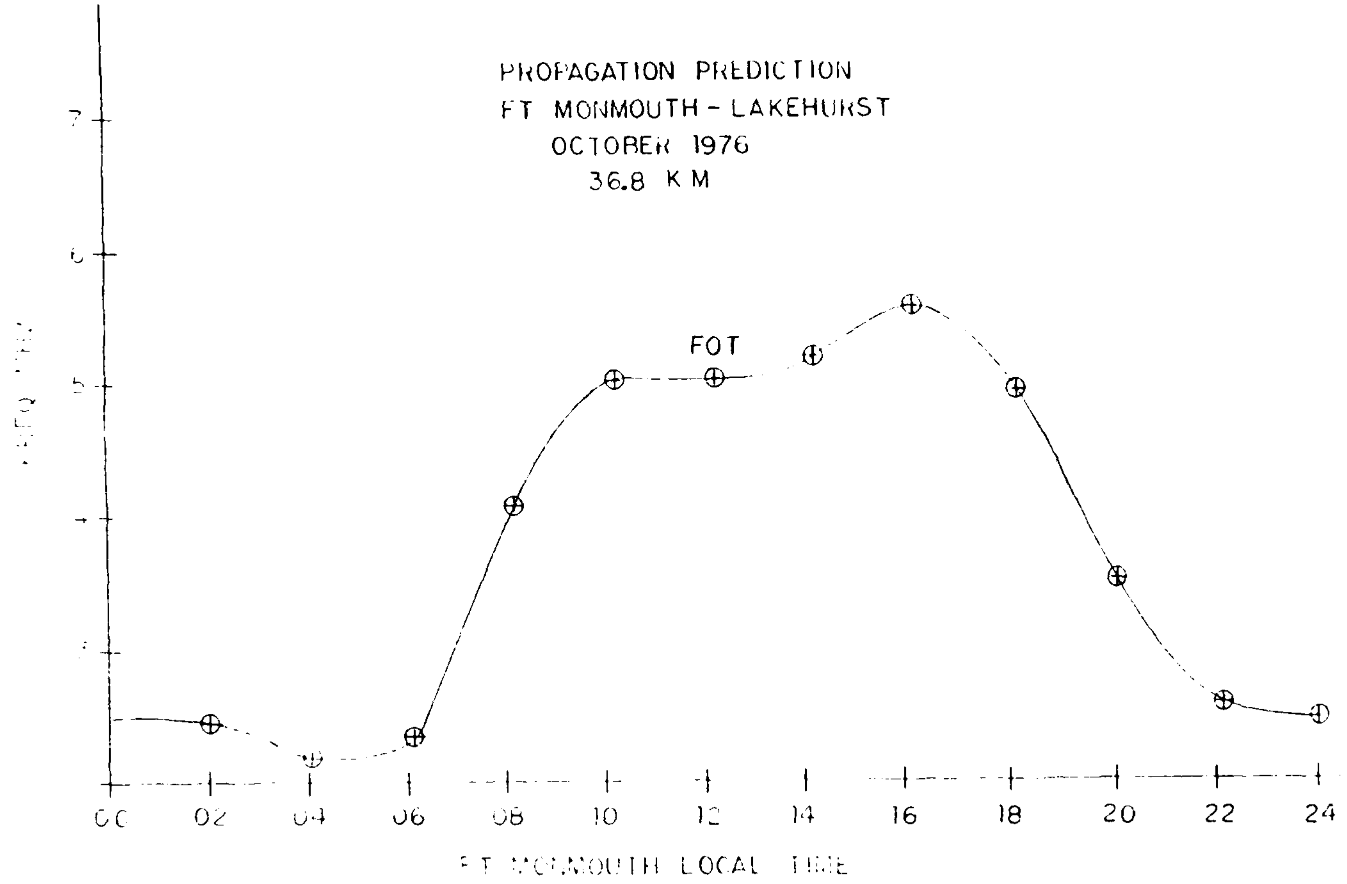


FIGURE 4-15. DIURNAL VARIATION OF FREQUENCY OF OPTIMUM TRANSMISSION (FOT)

TABLE 4-1. HF FREQUENCY RELIABILITY COMPUTER PRINTOUT

```
U.S.ARMY COMMUNICATIONS-ELECTRONICS ENGINEERING INSTALLATION AGENCY

                       FREQUENCY  RELIABILITY  TABLE

PROJECT 397   RPA 76500.0   ECA              SSN  11.5    OCTOBER    1976
FT MONMOUTH NJ    TO LAKEHURST NJ              AZIMUTHS     MILES      KM.
40.30N -  74.08W   40.03N -  74.33W   215.36  35.20     22.9      36.8
TYPE OF SERVICE CW  XMSN                      MINIMUM ANGLE #  -.0 DEGREES
XMTR  2 _ 31 HALF-WAVE         *H  9.14\ *L  -.50\ *A -C\ OFF AZ #    0
RCVR  2 _ 31 HALF-WAVE         *H  9.14\ *L  -.50\ *A -C\ OFF AZ #    0
POWER #     .200KW   3MHZ MAN-MADE NOISE # -145DBW     REQD.S/N # 30DB

                         FREQUENCIES IN MHZ
   UT   2.0  3.0  4.0  5.0  6.0  7.0  8.0  9.0   -    -    -

22 02   .94  .70  .16   -    -    -    -    -    -    -    -   REL.

00 04   .94  .60  .35   -    -    -    -    -    -    -    -   REL.

02 06   .93  .57  .05   -    -    -    -    -    -    -    -   REL.

04 08   .93  .28   -    -    -    -    -    -    -    -    -   REL.

06 10   .92  .30   -    -    -    -    -    -    -    -    -   REL.

08 12   .96  .38  .83  .44  .06   -    -    -    -    -    -   REL.

10 14   .97  .97  .97  .86  .50  .13   -    -    -    -    -   REL.

12 16   .96  .38  .95  .87  .61  .20   -    -    -    -    -   REL.

14 18   .97   -   .96  .90  .70  .32   -    -    -    -    -   REL.

16 20   .97  .37  .98  .93  .75  .30  .05   -    -    -    -   REL.



18 22   .93  .95  .94  .81  .43  .06   -    -    -    -    -   REL.

20 24   .96  .94  .64  .19   -    -    -    -    -    -    -   REL.

         20    22    00    02    04    06    08    10    12    14    16    18
   UT    00    02    04    06    08    10    12    14    16    18    20    22
  MUF   4.3   3.4   3.2   3.1   2.8   2.9   4.9   6.0   6.3   6.6   6.7   5.9
  FOT   3.4   2.6   2.4   2.4   2.2   2.3   4.0   4.9   4.9   5.1   5.4   4.7


DASHES IN RELIABILITY LINES SIGNIFY RELIABILITIES OF 00 PERCENT

PROVIDE UPDATE INFORMATION TO THIS AGENCY  ATTNO  CCC-EED-PED

FORT HUACHUCA, ARIZONA 85613
AUTOVON 879-6779
```

A practical scheme for determining the best frequency to use for a particular communication system that has access only to a limited number of frequencies is to scan all available frequencies periodically and choose that frequency displaying the best signal-to-noise ratio. This scheme can be implemented practically between two fixed stations of the system that are less than about 150 miles apart.

4.6.8 NVIS PATH LOSS CALCULATIONS

For practical purposes, the NVIS path loss may be thought to be composed of three component losses:

$$L_i = L_d + L_{ta} + L_f$$

where

L_d = Spreading loss due to up and down path distance
L_{ta} = Ionospheric absorbtion loss (turnaround loss)
L_f = Loss incurred by not operating at the FOT
(L_f = 0 db at the FOT)

4.6.9 SPREADING LOSS AND TURNAROUND LOSS, Ld & Lta

With the assumption of a 300km-high ionosphere (e.g., h' = 300 Km), the spreading loss L_d is calculated to vary between 108.41 db for a perfectly vertical path (ground range d = 0) and 109.4 db when the ground range is 186 miles, a change of only 0.99 db. Results taken from numerous soundings reported in reference 3 indicate a total loss including the turnaround loss L_{ta} of

$$110 \text{ db} < L < 130 \text{ db}$$

indicating a variation in turnaround loss of

$$1 \text{ db} < L_{ta} < 21 \text{ db}$$

4.6.10 NON-OPTIMUM FREQUENCY LOSS, LF

This loss in indicative of the penalty that must be paid for not having an assigned frequency corresponding exactly to the FOT. This penalty will vary with the time of day and the number of MHz removed from the FOT as indicated in figure 4-16.

Figure 4-16 indicates the penalty is most severe in the early morning (0600 to 0800) and late afternoon (1600 to 1900) and less severe at midday (1000 to 1400). When removed approximately ±2 MHz from the FOT, the penalty may be as high as 25 db. At ±1 MHz removed, the penalty may only be as high as 10 db in the morning and afternoon and less than 4 db at midday. In order to limit L_f to no more than about 10 db, a sufficient number of assigned frequencies should be available to permit operation always within about ±1 MHz of the FOT. If a 25 db penalty can be tolerated, frequencies available should fall within ±2 MHz of the FOT.

EXTRA EXPECTED LOSS WHEN OPERATING AT A FREQUENCY CLOSE TO THE BEST CHOICE FREQUENCY (f_o)

STATION TO STATION EXPERIMENTAL DATA DERIVED AT FT. MONMOUTH, NEW JERSEY AREA (JUNE 1976)

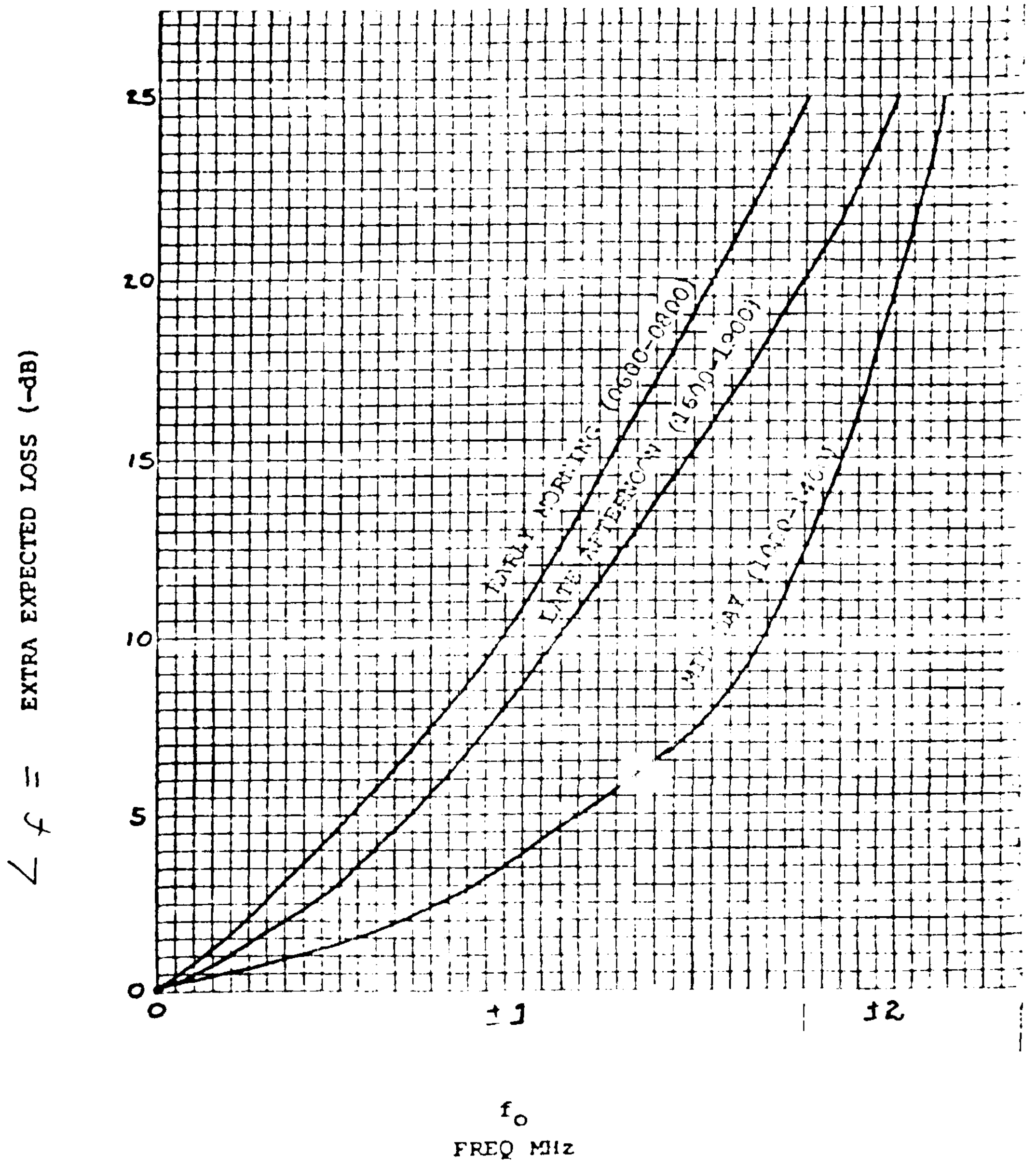


FIGURE 4-16. LOSS DUE TO NOT OPERATING EXACTLY AT FO

4.6.11 TRANSMITTER POWER REQUIRED TO ACHIEVE A GIVEN SIGNAL TO NOISE RATIO AT THE RECEIVER

The transmitter power required as a function of receiver signal-to-noise ratio is given by the following equation

$$P_T = L_i + S/N + N_a - G_T - G_R \qquad (14)$$

where

P_T = Transmitter power in db/μv
L_i = NVIS loss db
S/N = Signal to noise ration in db
N_a = Atmospheric noise db/μv
G_T = Gain of Transmitting antenna dbi
G_R = Gain of receiving antenna dbi

TABLE 4-2. REQUIRED TRANSMITTER POWER AS A FUNCTION OF SIGNAL TO NOISE RATIO ATMOSPHERIC NOISE AND ANTENNA GAINS

$110 \text{ db} < L_i < 130 \text{ db}$

					Transmitter Power Required		
	S/N db	N_a db/μv	G_T dbi	G_R dbi	P_T db/μv	P_T dbm	P_T
1	20	-10	0	0	130	+23	200 MW
2	20	-10	-10	-10	150	+43	2 watts
3	10	+10	-10	-10	160	+53	200 watts

The power required to achieve a useful signal-to-noise ratio for three cases was computed using equation 14 and is summarized in table 4-2. Table 4-2 illustrates that the transmitter power requirements are modest and not at all analogous to what is required in long distance hf radio.

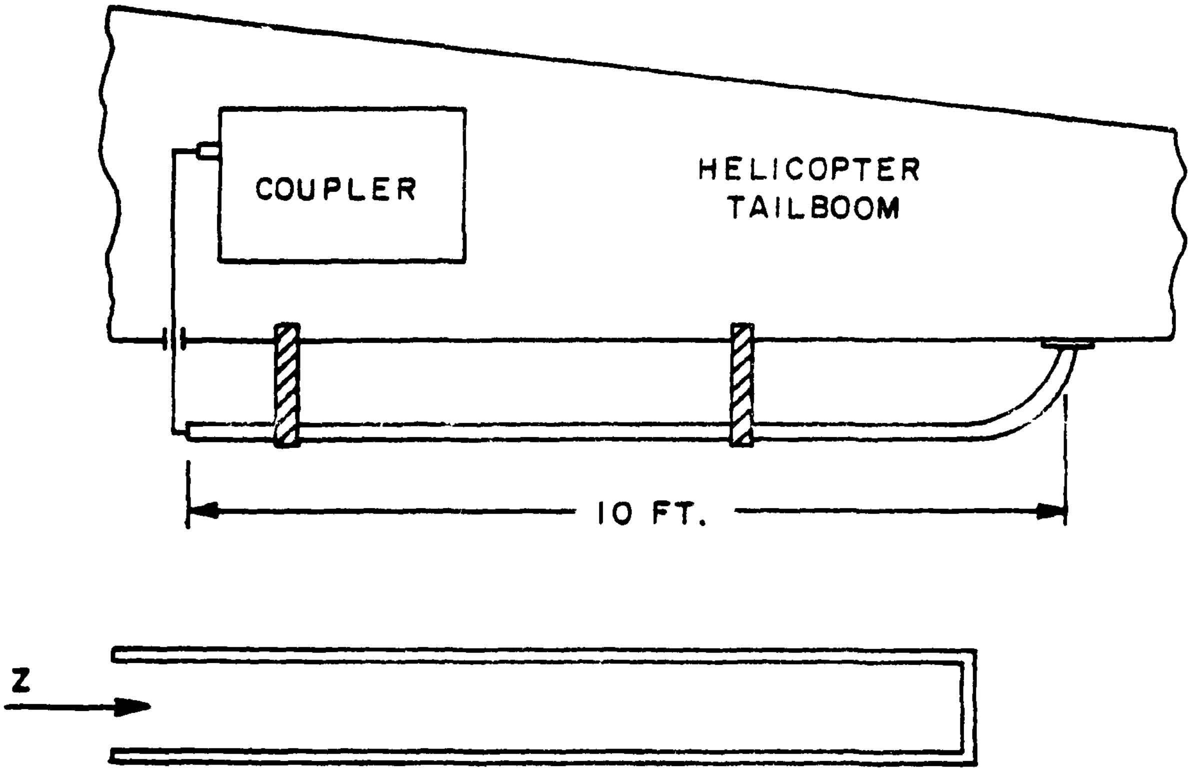

COUPLER
HELICOPTER TAILBOOM
10 FT.
Z

FIGURE 4-17. TRANLINE INSTALLED ON TAIL BOOM OF HELICOPTER

TABLE 4-3. SUMMARY OF MEASURED TRANLINE ANTENNA PATTERN CHARACTERISTIC

Frequency f MHz	Pattern Shape	Average Radiation in db/μv	Gain Above Dipole	Gain Above isotropic
2.025	OMNI	+11.3	-18.6	-16.6
2.527	OMNI	+29.1	-16.0	-14.0
3.375	OMNI	+38.2	-16.8	-14.8
4.312	OMNI	+41.5	-15.5	-13.5
5.338	OMNI	+39.	- 8.	- 6.
6.73	Dipole (Figure eight)	+35.23	- 9.3	- 7.3
8.80	Dipole (Figure eight)	+36.3	- 5.2	- 3.3

NOTES:

1. Measurements made by ECOM (Ref. 3)
2. Shorted transmission line exciter

4.6.12 AIRCRAFT ANTENNAS FOR NVIS

One of the primary problems of providing hf communications to small aircraft and helicopters is the lack of physical space for conventional hf antennas. The approach used by the Army (reference 3) to solve this problem is to make the entire airframe the antenna by means of suitable excitation techniques. It was found that the best excitation was produced by antenna concepts based upon the unbalanced shorted transmission line principle.

A sketch of a shorted transmission line coupler (called a Tranline) attached to a helicopter tail boom is shown in figure 4-17. Test results for this antenna measured at ECOM (reference 3) are summarized in Table 4-3. The patterns appear close to omnidirectional except for the higher frequencies where the airframe approaches a quarter wavelength and the patterns take on a figure eight shape typical of a dipole. The values of gains presented in table 4-3 show that antennas need not be highly efficient to provide reliable NVIS propagation.

4.6.13 IMPEDANCE OF THE TRANLINE

The impedance of the Tranline at low frequencies is highly inductive with a very small value of resistance, and a suitable coupler must be provided to match it to the transmitter or receiver. It can be compared to an air-cored coil, and the most efficient method of obtaining impedance matching is to simply bridge the antenna element with a variable capacitor as though it were a coil and then adjust the shunt capacitance to resonance. This method is suitable up to the highest NVIS frequency.

4.6.14 EQUIPMENT FOR NVIS COMMUNICATION

Several hf airborne transceivers are available today that can be adapted to NVIS communications. Some of these are listed in table 4-4. It should be noted that equipment listed in table 4-4 is for military service and may perhaps be modified for commercial service at costs considerably less than indicated in table 4-4.

TABLE 4-4. SOME TYPICAL HF RADIO EQUIPMENT THAT CAN BE ADAPTED FOR NVIS COMMUNICATION (NOT COMPREHENSIVE)

MFR	Type	Approx. 1981 Price Antenna	Intended Use	Freq. MHz	Trans. Power Watts	Sensitivity μv for 10 db S/N
Collins	718V-5	32K	Airborne	2-30	100	
Racal	TRA6900	10K	Manpack	2-16	10	
Hughes	AN/PRC-104	-	Manpack	2-30	20	

4.6.19 HF SPECTRUM AVAILABILITY FOR NVIS

NVIS will require several frequency assignments in the traditionally overcrowded 2- to 8-MHz band. Frequency assignments may not be readily available to implement NVIS unless a sufficiently strong argument for its use can be mounted based on low-flying aircraft densities, public service, and interference potential to other services presently using hf radio in conventional ways.

Before adopting NVIS for FAA use, it is recommended that a study be made into the hf frequency availability based upon:

1. Low-flying aircraft traffic densities,
2. Interference potential with other services using hf radio, and
3. Frequency reuse.

The following questions must be answered.

How much do they interfere with normal long-range hf services where signals are launched horizontally and receivers are thousands of miles from the transmitter?

NVIS launches waves vertically, and the service area is confined to within about 150 miles of the base station. There is a large skip zone surrounding the service area, and signals propagated beyond the skip zone are severely attenuated. Is it possible, therefore, to reuse NVIS frequency assignments in adjacent service areas without serious interference between neighboring NVIS systems or remote service areas beyond the skip zone? Just what are the separation criteria?

APPENDIX A

FAA ACTIVITIES DIRECTED AT IMPROVING COMMUNICATIONS TO HELICOPTERS IN THE GULF OF MEXICO[1]

1.0 GULF OF MEXICO OFFSHORE OPERATIONS - air/ground communications

Concentrated planning efforts have been underway in the Southwest Region since early 1979 on expanding helicopter IFR/VFR operations in the Gulf of Mexico. Various Washington offices, oil and helicopter industries, and all organizational levels of the region were involved.

2.0 REQUIREMENTS

a. Today, a large force of helicopters operated by the oil companies and by transportation service companies provides air transportation for the more than 2,000 oil and gas platforms located in the Gulf. The helicopters are used to transport personnel, crew support supplies, well drilling and service equipment, etc., in support of every facet of oil and gas exploration, development, and production. This presently entails about 580,000 aircraft movements and 3,400,000 passengers carried annually. Nearly all the operations are presently conducted VFR.

b. One of the transportation service companies, Petroleum Helicopters, Inc. is flying IFR offshore on a very limited basis using VLF Omega for navigation and company operated communications and weather observation stations. Fourteen IFR routes have been established in the Gulf predicated on, but not actually depending on, the radials of VOR's located along the Gulf shore. These routes are not in the common public use airway system but are available to all users by application under FAR's.

c. With the increased costs of oil exploration/production, the emphasis on increasing domestic oil production brought on by energy shortages, and advancement in helicopter capability in recent years, there is now a definite and immediate need for expanding the operation, especially IFR capability.

d. As a result of a November 9, 1978 letter from the Helicopter Safety Advisory Committee and coordination at the FAA regional director level, planning efforts to expand the Gulf helicopter operations, which were started in 1974 but later dropped, were renewed. A special task force made up of oil and helicopter, FAA and National Weather Service (NWS) representatives was established to explore problem areas, exchange ideas and identify needs for offshore helicopter activity. A series of working meetings have since been held, and it has been determined that the most critical need for expanding IFR/VFR operations is direct pilot to FAA facility communications.

3.0 COMMUNICATIONS PLANNING

a. A/G communications are to be provided in the Gulf area from about 180 miles east of New Orleans, Louisiana, west to Galveston, Texas, and out to about 150 miles offshore.

[1] The primary source of this information was Federal Aviation Administration, FY 1980 Cost Estimates, RIS BU2500-5, Federal Aviation Administration, Washington, D.C. 20591, undated internal document.

b. Installation [illegible] a total of [illegible] outlets, 10 [illegible] Eight of these outlets are to be used by the Houston [illegible], [illegible] facilities, and five by FSS's.

c. Through collocation [illegible] only 10 new sites will be established [illegible] platforms.

d. Remoting of the outlets [illegible] circuits or a combination [illegible] microwave systems.

e. FAA installation and maintenance of all [illegible] planned, however, the feasibility of contracting the [illegible] for the offshore facilities is being explored.

3.1 FACILITY PLANNING

a. Using projections of activity and [illegible] A/G communications needs were defined to provide [illegible] communications to the surface of onshore landing points, [illegible] the terminal facility and ARTCC controlled airspace, [illegible] to [illegible] surface of selected offshore platform landing pads. Specific [illegible] are:

(1) For the Houston ARTCC, within the [illegible], Baton Rouge, and Harvey Sectors, en route coverage [illegible] MSL through FL 240 and from platform level to [illegible] of offshore blocks High Island 581, [illegible], [illegible], Eugene Island 330, and [illegible].

(2) For the FSS's, [illegible] ARTCC Beaumont Sector (Houston [illegible], [illegible], [illegible] Harvey Sectors (New Orleans FSS).

(3) For terminal facilities, [illegible] landing points listed below plus the [illegible] coverage [illegible]

Location	[illegible]
Galveston Scholes Field [illegible]	[illegible] nautical [illegible] 190° [illegible].
Sabine Pass Heliport (Beaumont) and Cameron Heliport (Lake Charles)	500 to 6,000 feet MSL within [illegible] nautical mile radius of the heliport.
Intracoastal City Heliport (Lafayette) and Morgan City Heliport (New Orleans)	500 to [illegible] feet MSL [illegible] nautical [illegible].

Location	Coverage
Houma Airport (New Orleans)	500 to 7,000 feet MSL within a 30 nautical mile radius of the airport.

Only VHF communications are required for all of the above for use with civil aircraft in the area. There is no requirement for UHF communications for use with military aircraft.

b. Engineering studies conducted by Aeronautical Radio, Inc., under a contract with the FAA Southwest Region engineers resulted in recommendations for the following 18 A/G outlets to satisfy the coverage requirements:

Houston ARTCC

(1) Sabine Pass
(2) Intracoastal City
(3) Venice
(4) High Island 582
(5) West Cameron 587
(6) Vermillion 245A
(7) Eugene Island 330
(8) South Timbalier 190

Terminals

(1) Sabine Pass (Beaumont)
(2) Cameron (Lake Charles)
(3) Intracoastal City (Lafayette)
(4) Morgan City (New Orleans)
(5) Houma (New Orleans)

FSS's

(1) Morgan City (New Orleans)
(2) Venice (New Orleans)
(3) Vermillion 245A (New Orleans)
(4) South Timbalier (New Orleans)
(5) High Island 582 (Houston)

c. Plans are to establish conventional facilities onshore in existing leased space on the airports except that battery standby power is proposed in lieu of engine generators. The offshore facilities are to be located on oil company platforms with plants items, including shelter and antenna support, to be provided by the owner to meet FAA requirements. Primary power would be provided from the platform engine/generator supplied system with FAA batteries for standby.

The existing RTR facility at Houma Airport is to be used and collocation of outlets is planned at the following locations to reduce the number of new sites that will have to be established: Onshore at Sabine Pass, Intracoastal City, Morgan City, and Venice and offshore for High Island 582, Vermillion 245A, and South Timbalier 190. In addition to these 7 new collocated sites, 3 others are planned at Cameron onshore and West Cameron 587 and Eugene Island 330 offshore for a total of 10 new sites, 5 onshore and 5 offshore.

d. Remoting of the onshore outlets is planned via leased commercial telephone circuits. Remoting of the offshore outlets is planned via leased circuits on existing oil company microwave systems between the offshore platforms and the onshore terminating points of the microwave systems, and then leased commercial telephone circuits between those points and the FAA controlling facilities.

e. Current plans are to both install and maintain the electronics equipment utilizing FAA personnel in the usual manner but recognizing that the offshore facilities will present some new and different problems. A regional contract for helicopter transportation of personnel on as as-required basis is planned. A proposed special maintenance concept for the offshore facilities will be developed and submitted by separate correspondence to the Airway Facilities Service. Concentrated efforts will also be made to expedite Remote Maintenance Monitoring for the offshore sites from the ongoing program for RCAG's.

4.0 IMPLEMENTATION

a. The following priority order for implementing the planned A/G outlets was developed jointly by the FAA and oil/helicopter industry representatives at the October 11, 1979 task force meeting:

(1) Intracoastal City - ARTCC and Terminal
Vermillion 245A - ARTCC and FSS.

(2) Eugene Island 330 - ARTCC.

(3) Sabine Pass - ARTCC and Terminal
West Cameron 587 - ARTCC.

(4) High Island 582 - ARTCC and FSS
Morgan City - Terminal and FSS
Cameron - Terminal

(5) South Timbalier 190 - ARTCC and FSS.

(6) Venice - ARTCC and FSS.

b. Plans are to implement the outlets in the above order as rapidly as possible after funds and equipment are made available.

5.0 Status

Phase I, Intracoastal City and Vermillion 245C

a. Two Intracoastal City outlets, 120.35 MHz for ARTCC and 121.35 MHz for the Lafayette TRACON were commissioned on August 15, 1980. Reported coverage of this facility is good and somewhat more than predicted.

b. Following some delays in getting antennas installed on Vermillion 245C and microwave links from the platform to Lafayette two outlets 122.0 MHz for the New Orleans FSS and 120.35 MHz for the ARTCC were put into operational test on September 9, 1980 and commissioned on September 16, 1980.

APPENDIX B

DEFINITION OF A STANDARD AIRCRAFT RECEIVING SYSTEM FOR USE WITH ECAC PLOTS

The power density at the aircraft as derived from the ECAC plots is

$$Pd = 10 \log \left(\frac{W}{10^{-3}} \right) \quad dbm/m^2$$

where

Pd = Power density in dbm/m^2

W = Power density in $watts/m^2$

The power delivered by the antenna to a matched cable at the terminals of the antenna is

$$Wt = W\, Ae$$

Wt = Power delivered to matched cable-watts

W = Power density into antenna in $Watts/m^2$

Ae = Effective antenna aperature m^2

from Kraus,* page 50, eq. 3-35 for a short dipole

$Ae = .119\ \lambda^2$

at 120 MHz $\lambda = 2.5$ m

$\therefore Ae = .743\ m^2$ at 120 MHz

$$\therefore Wt = 10^{-3} \left(\log^{-1} \frac{Pd}{10} \right) (.743) \quad watts$$

---

*Kraus "Antennas", McGraw Hill Book Co., Inc. 1950 in dbm

$$Pt = 10 \log \left(\frac{Wt}{10^{-3}} \right)$$

$$Pt = 10 \log \left[\left(\log^{-1} \frac{Pd}{10} \right) .743 \right]$$

$$Pt = Pd + 10 \log .743$$

$$= Pd - 1.29 \text{ db}$$

The power into the receiver at the end of a cable at 120 MHz is

$$Pr = Pt - Lc = Pd - 1.29 - Lc \text{ dbm}$$

Pr = Power into receiver in dbm 120 MHz
Pt = Power delivered to matched cable in dbm
Lc = Cable loss
-1.29 = 10 log Ae = 10 log .119 λ^2 @ 120 MHz
Ae = Antenna aperture in m^2

Definition of Standard Aircraft Receiving System for low flying aircraft.

A standard Receiving System has the following components:

(1) Standard Receiver per U.S. National Aviation Standard for VHF Air to Ground Communications System 6510.6 Paragraph 3.2.3.1

Available Received Carrier Power Pr	Percent Modulation	Minimum (S+N/N)
- 96 to - 70 dbm	30	6 db
- 70 to - 10 dbm	30	25 db

(2) A cable loss of no more than 3 db.

(3) An antenna equivalent to a short dipole
Effective aperture A = 0.119 λ^2
or gain over isotropic of 1.76 db with VSWR less than 2.1.

The power into the receiver is obtained from the power density, as plotted by the ECAC plots, by means of the following equation.

Pr = Pd - 4.29 db

Pr = Power into the receiver in dbm
Pd = Power density from FCAC plots in dbm/m^2
4.29 db includes the cable loss of 3 db and the effective aperture of a short dipole at 120 MHz.

The operator may determine his coverage capability by comparing his receiver system with the Standard System. If it is better he will experience greater coverage, if it is poorer he will experience poorer coverage.

APPENDIX C

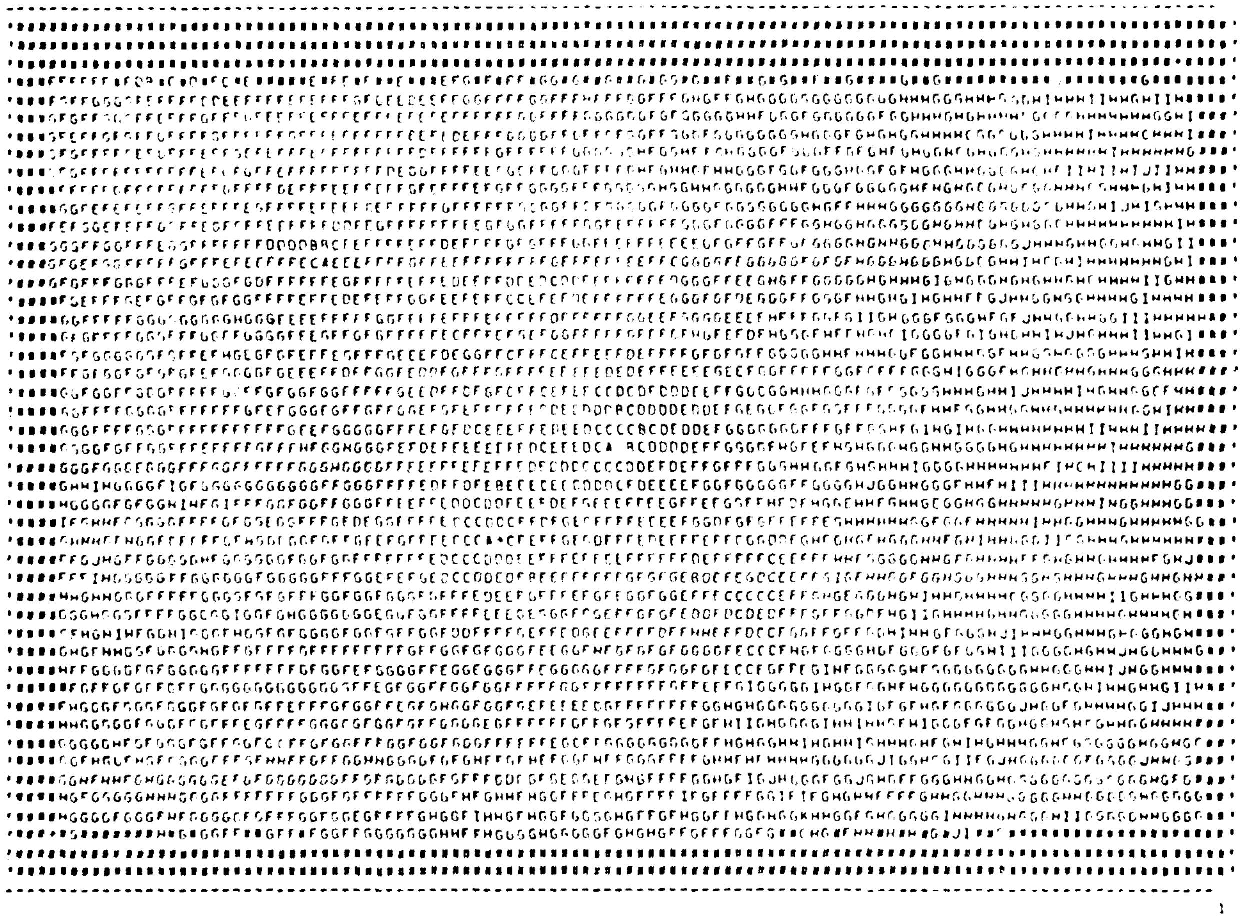
POWER DENSITY PLOTS FOR APPALACHIA

(a) Power density plots, Charleston, Rainelle, Beckley, Henderson,

(b) Power density plots, Charleston, High Gain Antenna Pointed South.

(c) Power density plots, Charleston, Rainelle, Beckley, Henderson, Bolt

(d) Power density plots, Charleston, Rainelle, Beckley, Henderson, Flat Top



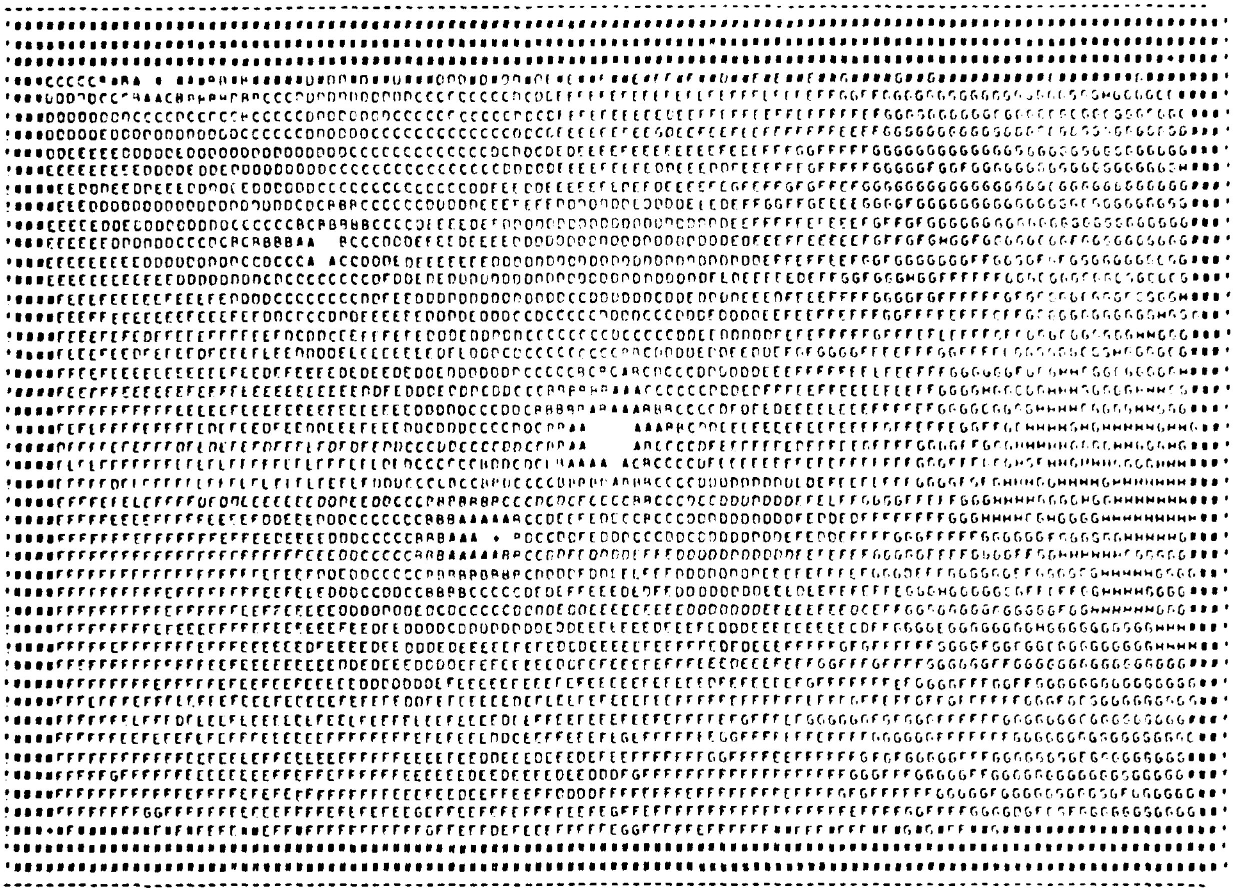
```
MAP OFSURFACE   35   ,  SURFACE    2
 POWER DENSITY OF CHARLESTON, RAINELLE, HENDERSON, BECKLEY AT 10    FT              \

  374649.0     810725.0  LAT & LON OF SITE

  371000.0     821000.0  LAT & LON OF SW TIC MARK

  384500.0     791900.0  LAT & LON OF NE TIC MARK
                     >     -50.000
  -50.000  >= A  >     -60.000
  -60.000  >= B  >     -70.000
  -70.000  >= C  >     -80.000
  -80.000  >= D  >     -90.000
  -90.000  >= E  >    -100.000
 -100.000  >= F  >    -110.000
 -110.000  >= G  >    -120.000
 -120.000  >= H  >    -130.000
 -130.000  >= I  >    -140.000
 -140.000  >= J  >    -150.000
 -150.000  >= K  >    -160.000
 -160.000  >= L  >    -170.000
 -170.000  >= M  >    -180.000
 -180.000  >= N  >    -190.000
 -190.000  >= O  >    -200.000
 -200.000  >= P  >    -210.000
 -210.000  >= Q  >    -220.000
 -220.000  >= R  >    -230.000
 -230.000  >= S  >    -240.000
 -240.000  >= T  >    -250.000
 -250.000  >= U  >    -260.000
 -260.000  >= V  >    -270.000
 -270.000  >= W  >    -280.000
 -280.000  >= X  >    -290.000
 -290.000  >= Y  >    -300.000
 -300.000  >= Z  >    -310.000
 -310.000  >= 1  >    -320.000
 -320.000  >= 2  >    -330.000
 -330.000  >= 3  >    -340.000
 -340.000  >= 4  >    -350.000
 -350.000  >= 5  >    -360.000
 -360.000  >= 6  >    -370.000
 -370.000  >= 7  >    -380.000
 [illegible]
 [illegible]
```

FIGURE C-1



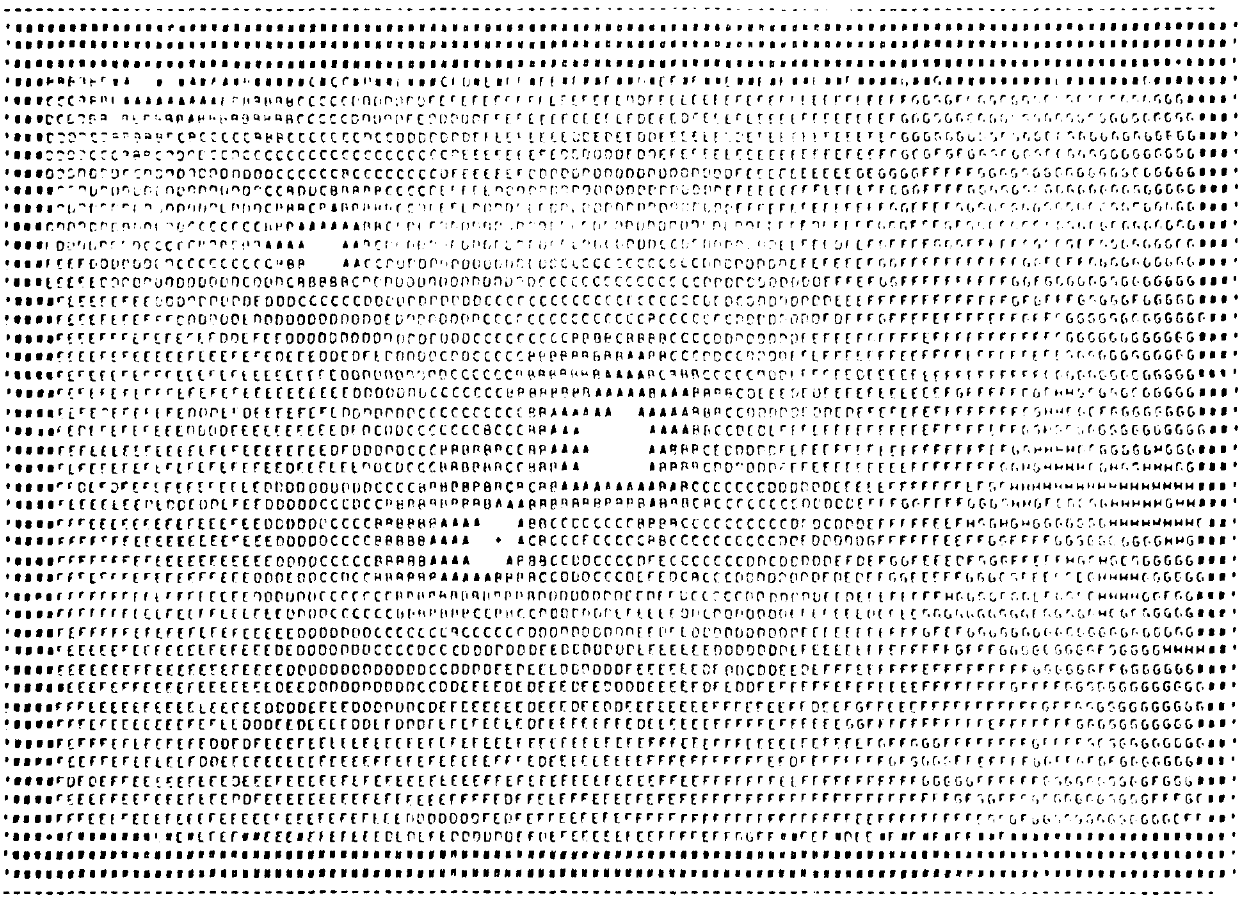
```
                                                                                                                          1
MAX OF SURFACE  36  ,  SURFACE   7
 POWER DENSITY OF CHARLESTON, RAINELLE, HENDERSON, BECKLEY AT 500  FT                  \

  374649.0     810725.0  LAT & LON OF SITE

  371000.0     821700.0  LAT & LON OF SW TIC MARK

  384500.0     791900.0  LAT & LON OF NE TIC MARK
                    >    -50.000
  -50.000 >= A >    -60.000
  -60.000 >= B >    -70.000
  -70.000 >= C >    -80.000
  -80.000 >= D >    -90.000
  -90.000 >= E >   -100.000
 -100.000 >= F >   -110.000
 -110.000 >= G >   -120.000
 -120.000 >= H >   -130.000
 -130.000 >= I >   -140.000
 -140.000 >= J >   -150.000
 -150.000 >= K >   -160.000
 -160.000 >= L >   -170.000
 -170.000 >= M >   -180.000
 -180.000 >= N >   -190.000
 -190.000 >= O >   -200.000
 -200.000 >= P >   -210.000
 -210.000 >= Q >   -220.000
 -220.000 >= R >   -230.000
 -230.000 >= S >   -240.000
 -240.000 >= T >   -250.000
 -250.000 >= U >   -260.000
 -260.000 >= V >   -270.000
 -270.000 >= W >   -280.000
 -280.000 >= X >   -290.000
 -290.000 >= Y >   -300.000
 -300.000 >= Z >   -310.000
 -310.000 >= 1 >   -320.000
 -320.000 >= 2 >   -330.000
 -330.000 >= 3 >   -340.000
 -340.000 >= 4 >   -350.000
 -350.000 >= 5 >   -360.000
 -360.000 >= 6 >   -370.000
 -370.000 >= 7 >   -380.000
 -380.000 >= [illegible] >   [illegible]
```

FIGURE C-2



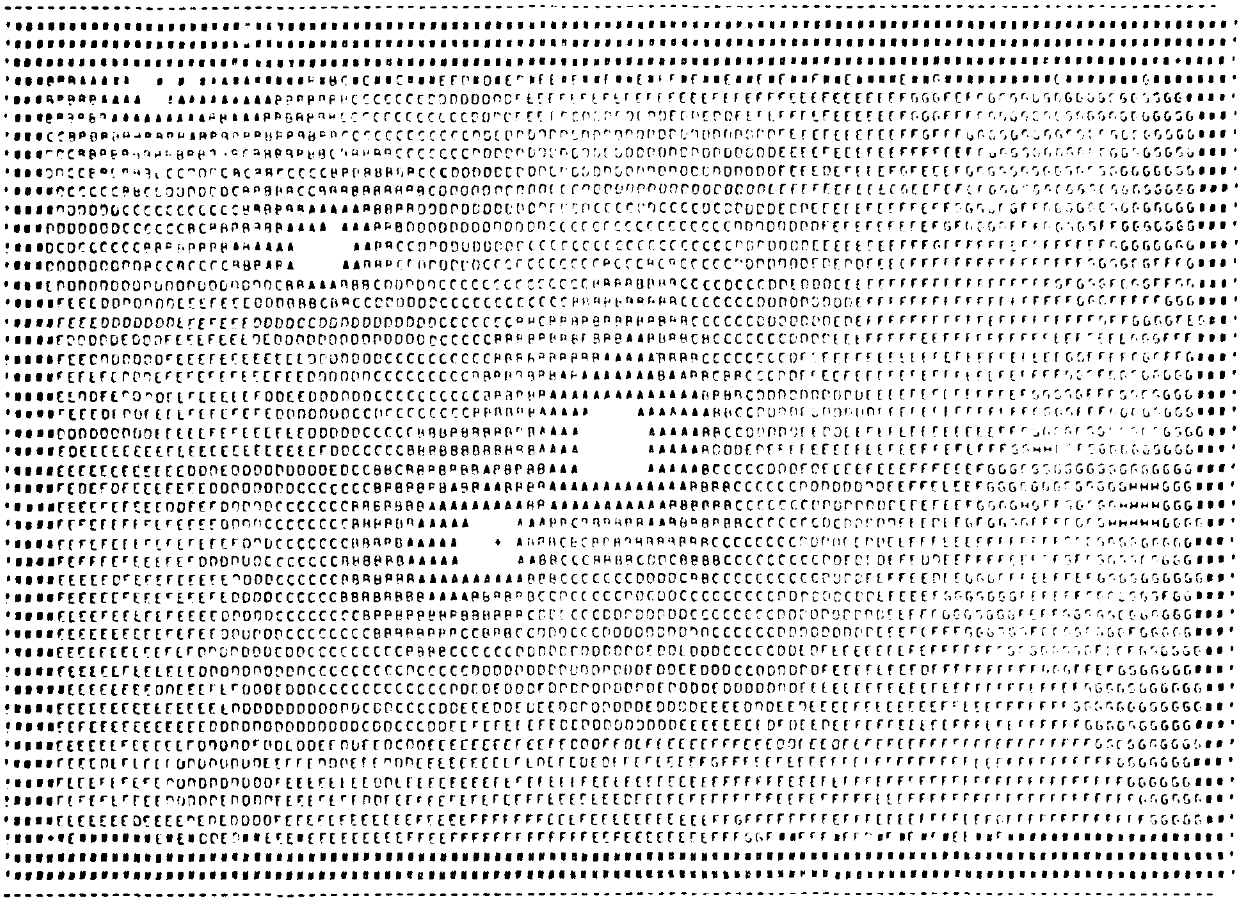
```
                                                                                                             1
MAX OFSURFACE  77  .  SURFACE  12
 POWER DENSITY OF CHARLESTON, RAINELLE, HENDERSON, BECKLEY AT 1000 FT

  374649.0     811725.   LAT & LON OF CITY

  371000.0     821700.0  LAT & LON OF SW TIC MARK

  384530.0     791930.0  LAT & LON OF NE TIC MARK
                     >     -50.000
  -50.000  >=  A  >     -60.000
  -60.000  >=  B  >     -70.000
  -70.000  >=  C  >     -80.000
  -80.000  >=  D  >     -90.000
  -90.000  >=  E  >    -100.000
 -100.000  >=  F  >    -110.000
 -110.000  >=  G  >    -120.000
 -120.000  >=  H  >    -130.000
 -130.000  >=  I  >    -140.000
 -140.000  >=  J  >    -150.000
 -150.000  >=  K  >    -160.000
 -160.000  >=  L  >    -170.000
 -170.000  >=  M  >    -180.000
 -180.000  >=  N  >    -190.000
 -190.000  >=  O  >    -200.000
 -200.000  >=  P  >    -210.000
 -210.000  >=  Q  >    -220.000
 -220.000  >=  R  >    -230.000
 -230.000  >=  S  >    -240.000
 -240.000  >=  T  >    -250.000
 -250.000  >=  U  >    -260.000
 -260.000  >=  V  >    -270.000
 -270.000  >=  W  >    -280.000
 -280.000  >=  X  >    -290.000
 -290.000  >=  Y  >    -300.000
 -300.000  >=  Z  >    -310.000
 -310.000  >=  1  >    -320.000
 -320.000  >=  2  >    -330.000
 -330.000  >=  3  >    -340.000
 -340.000  >=  4  >    -350.000
 -350.000  >=  5  >    -360.000
 -360.000  >=  6  >    -370.000
 -370.000  >=  7  >    -380.000
 -380.000  >=  8  >    -390.000
          .     >
```

FIGURE C-3



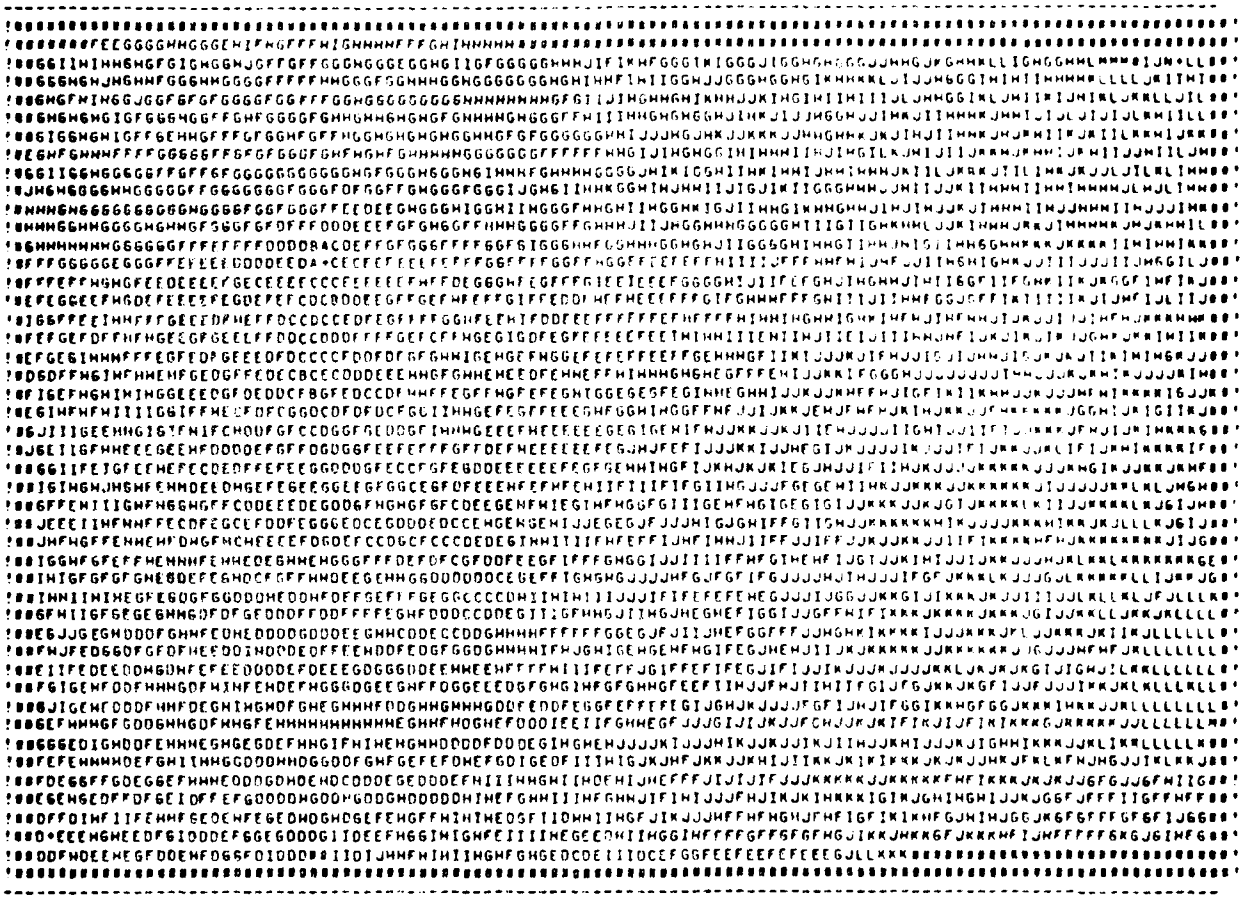
```
MAX OFSURFACE   38   ,  SURFACE   17
 POWER DENSITY OF CHARLESTON, RAINELLE, HENDERSON, BECKLEY AT [illegible] FT

  374649.0     810725.0  LAT & LON OF SITE

  371000.0     821000.0  LAT & LON OF SW TIC MARK

  394500.0     791000.0  LAT & LON OF NE TIC MARK
                 >    -50.000
  -50.000 >= A >    -60.000
  -60.000 >= B >    -70.000
  -70.000 >= C >    -80.000
  -80.000 >= D >    -90.000
  -90.000 >= E >   -100.000
 -100.000 >= F >   -110.000
 -110.000 >= G >   -120.000
 -120.000 >= H >   -130.000
 -130.000 >= I >   -140.000
 -140.000 >= J >   -150.000
 -150.000 >= K >   -160.000
 -160.000 >= L >   -170.000
 -170.000 >= M >   -180.000
 -180.000 >= N >   -190.000
 -190.000 >= O >   -200.000
 -200.000 >= P >   -210.000
 -210.000 >= Q >   -220.000
 -220.000 >= R >   -230.000
 -230.000 >= S >   -240.000
 -240.000 >= T >   -250.000
 -250.000 >= U >   -260.000
 -260.000 >= V >   -270.000
 -270.000 >= W >   -280.000
 -280.000 >= X >   -290.000
 -290.000 >= Y >   -300.000
 -300.000 >= Z >   -310.000
 -310.000 >= 1 >   -320.000
 -320.000 >= 2 >   -330.000
 -330.000 >= 3 >   -340.000
 -340.000 >= 4 >   -350.000
 -350.000 >= 5 >   -360.000
 -360.000 >= 6 >   -370.000
 -370.000 >= 7 >   -380.000
 -380.000 >  8 >   -390.000
 -   .     >
```

FIGURE C-4



```
                                                                                                 1
 CHARLESTON     TX ANT 20 FT   RX ANT 10 FT   POWER 40 DBM   FREQ 120 MHZ

 382146.0      813518.0   LAT & LON OF SITE

 371000.0      821700.0   LAT & LON OF SW TIC MARK

 384500.0      791900.0   LAT & LON OF NE TIC MARK
                    >      -50.000
  -50.000  >=  A  >      -60.000
  -60.000  >=  B  >      -70.000
  -70.000  >=  C  >      -80.000
  -80.000  >=  D  >      -90.000
  -90.000  >=  E  >     -100.000
 -100.000  >=  F  >     -110.000
 -110.000  >=  G  >     -120.000
 -120.000  >=  H  >     -130.000
 -130.000  >=  I  >     -140.000
 -140.000  >=  J  >     -150.000
 -150.000  >=  K  >     -160.000
 -160.000  >=  L  >     -170.000
 -170.000  >=  M  >     -180.000
 -180.000  >=  N  >     -190.000
 -190.000  >=  O  >     -200.000
 -200.000  >=  P  >     -210.000
 -210.000  >=  Q  >     -220.000
 -220.000  >=  R  >     -230.000
 -230.000  >=  S  >     -240.000
 -240.000  >=  T  >     -250.000
 -250.000  >=  U  >     -260.000
 -260.000  >=  V  >     -270.000
 -270.000  >=  W  >     -280.000
 -280.000  >   X  >     -290.000
 -290.000  >=  Y  >     -300.000
 -300.000  >=  Z  >     -310.000
 -310.000  >=  1  >     -320.000
 -320.000  >=  2  >     -330.000
 -330.000  >=  3  >     -340.000
 -340.000  >=  4  >     -350.000
 -350.000  >=  5  >     -360.000
 -360.000  >=  6  >     -370.000
 -370.000  >=  7  >     -380.000
 -380.000  >=  8  >     -390.000
 -390.000  >   9
```

FIGURE C-[illegible]

```
-------------------------------------------------------------------------------------------------------------------------------
!##############################################################################################################################'
'#########################FG#########EF##F#####################################################################################'
'##FGFFFFFFFFFFFF#EEEEEEEEFFFFFFFFF!EFEFFFFEFEFEFFFF#FFFFFFFFF###GHG####HG###H######H####H####G###################•#H##'
'###FFFFFFFFEFFFFEFFEFFF+FFEFFEFEFEFEEEEEFFFFFFFFGGGGGGGGGGGGGGGGHHHHHHHHHHHHHIIHGGGGGGGGGGGGGGGGGGGH##IHH#IHHH##'
!##FEFFFFFFEFFFEFFFEEEFFFFEEEFEFFEEEEEFFFEEEEEEFFFFGGFGGGGGGGGGHGGHHHHHHHHHHHHHHHHHGGGGGGGGGGGGGGGGGHLIHHHHHHHH##'
!###FFFFFFFEEEEEEEFEEEFFIEFEFEFEEEEEFFFFEFEFEFEEEFFEEEEEFFGGGGGGGGGGGGGGGHGGHHHHHHHHHHHHHGGGGGGGGGGGGGGGGHHIHHHHHHHH###'
'##FFFEFFEFFEEEEEEEEEEEEFEFFEEEEEDEEFFFEEEEEEDFEEEFEFFFFGGGGGGGGGGGGHHHGGHGGGHHHHHHHHHHHGGGGGGGGGGGGGGGGGHHJHHHHHHHHH###'
'##FFFFFFFEEEEEEEFEEEEEFEDDEDDDCDCDDFUDDDDFFEEFFEFFFGGGGGGGGGGGGHHGGGCGGHGHHHGGGHJHGGGGGGGHHGGGHHHHHHHHHHHHHHHHH###'
'##FFFEEEEEEEEEEEFEFEEEFEFDDDFEECCCDCDDCCDDDEEEFEFFF SGGGGGGGGGGGGGGGGGGGGGGGHHHGGGGGGGGGGGGJHHHHHHHHHHHHHHHHHHHH###'
'##FGFFEEEEEEEEEEEEEEEEEEEFDDDDDDCBACCCCCCDEFEFEFFFFFGGFFGGGGGGGGGFFGGGGGGGHGGGGGGHHHHIHGGGGHGHHHHHHHHHHHHHHHHHH###'
!##FFFFFFEEEEEEEEEEDDDDDDDCCCCPBPDCCCCDDFEEFFFFFGGFGFFFFGFGFFGGGGGGGGGGGGGGGHHHGGGHGGGGGHIHGHHHHHHHHHHHHHHHHHHHH###'
'##FFFFFFEEEEEEEDDDDDDUCCDCBBDCAABBBCDDDEEEFFFEFFFGGGGGGGFFFFFGGGGGGGGGGGGGHHGGGGGGGGGGHHGGGGGHHHHHHHHHHHHHHHHHHJ##'
'##FEEEEEEEEDDDDDCCCCCHBABBAA    ABCCDDDDDEEEFFFFFFFFFFFFFFFFFFFFGGGGGGGGFFGGGGGGGGGGGGHGHHGGGGGGHHHGHHHHHHGHGHHIJH##'
'##DDDDDDDDDCBCCBCBABBBPBBBA • AABBCCDDDCDDDDDDEEEEEEFDELDEEEFFFFFFFFEEFFFEFFFFFFFFFGGFGHIGFFFFFFFFFGHGGIIHGGGGGGHH###'
'##EDDDDDDDCCCCCCCCCCCCCCCCBB    ABCCCCCDDDDDDEEFEEEEEFDFEEEEEEEEFEFFFFEEEEEFIFFEEEEFGFEEEEEEFFFFFFFFIIHFFFFFFFGG###'
'##FEDDEDDDDDDDDDDDCCCCCCBAAAAABCCDDDDCEECFFFEFEDEEFEFFFFEFEFFFFFFFFFFFFFFFEEFFFFFFGFGFFEEEEEFEEEEGIFFGFGIGFFFFHHIGFF##'
!##ECDDFEDDDDDDDDDDDCCCCCAAAAAADDDECDEEEEEEFFFGEEFEFFFFFFFFFFFFFFFFFFFFFFFFFEFEEEEFHGEEEEEEEEEFFFFIGFHHFGFFFFIHHFG###'
'##EEDDEEEDEDCDDDDDDCCCCCBBPBAAHCDCEDDEEDDEDEFFFFEEFFFFFFFFFFFFFFFFEEFFFFFFFFFFGGFEGHFFEEEEEEEEFHFFFFFFGIFFIHHIHFFG###!
'##FEEEEFFFDDDCDDDDDCCCDDCCCCCBPABACDFDFEDEEGFEFFFFFFFFFFFFFFFFFFFFEFFFFFFFFHGFGGIFFEEEEEFFEEEFFIGFFFFHHFFFFGIGFIH###'
!##FEFEEEEEDDDDDDDCDDDDCCCCCCBABACDDDDDEFEGEFFFFFEFFFFFEEEEFEEEFFEEFFFEFFHHIFEEEEFGFFEFFGGFFFIHIGGFFFHGFFGIG###'
!##FFEEDEEFFEDDDDCEDCBBBCDDCCCBACCDDDDEEEEEEFFEEEEFFFEFFEEEEEEEFEFFFGGHHGFHGEEEEEEEEEGHGFFFFFGJIIIGFFGJGFFFFFFF#'
'##EFFEDDFFFEDDDDDEDDDCBCDDDDDBCBBBBEDDEFEEEFEFEFEEFFFFFFEEFEFEFEEEFEEEFEEFFFFHHIGGFFJIIHGFFFFFFFFFFHGFF##'
'##FFFFFEEFFFEDEEEEEDDCCCDDDDDDBBABBCCDDEEEEEEEEEFFFFEEFFFFFEEEFEEFFFEFFEFFHIIGIHHFEEFGGGEFFFGIGFFFFGHIIIFFFFGHFFFGGJGFF##'
!##FFFFFEFFFEFFFEFEDCCCDCDDCDDCBBCDCCCCDDEEEEDEDEFEEFFEEEEEEEEFEFEEGIHFFGEFEEEFHFEFEEGIIHGFFFGIIIIIJFFIHFFGJIFFF###'
!##FFFFFFFFFFFFEEEEEEDDDDDDDDDDDDCCCCDCDDCCDFEEEEEEEEEEEEEEEFEEEEEEEFFEEFFIGHGFEEEEEFFHFEEEFFFHIGEEGJIJIIFIGFFGGIIIJJHFF###'
!##FFFFFFFFEFFFFFEDDDDDDDDCDDCDDCCFCDCCDCCEEEEEFFEEEEEEFFEEEFEEEFFEEEFFFEFIHFHIEFFHIJJIIHJGFGGIIJJIJIGGF##'
!##FFFFFFFFEFFFFFEECCDDDDDDDCDDCDDCEDCCCHCCCDEEEEEFGEEGFFEEEEEFEEEEEEEEEEEEFGFFFEFHHIGFIHEGIIIIIIIGFIHIHIIIIHGFGHF##'
'###EEEEEEFFFFEDDCDDDDDDDCDCBCCCDDCCCCCCCCDEEEEFEEFEGGEEEFEEEEEEEEEEEFEEEFGIGEEFHIIHFHIFFIIJJIIHFFGIIHIJJIJHFFF###'
!##HEEEEEFFFFFCDCFDDCDDDDDDDCCCCDCCCCCCCDCCDEEEEFEFFEEFEEEEFEFEEEEEEFFFEFEEEHGEEFHIIHFHIGFFGFIJJIIGFHJJIIIIIIIGFFF##'
!##EEFEEEFFFEDDDDDDDEEDDDDCDDCDCCCCCCCCCDDDCCDEEFFEFGEEEEEEGHHFEEEEEEEEEEEEEFEEEEGHFHHGGFEGGGGIIIGGHGJIIJJIIFIHFFFF##'
!##EEEEEFFFFFDEDDDDDDDDCDCDDDDCCCCCCCCCCCDCDDCCDFFFFLEFEFFEFHGHFEEEEEEEEEELEEEEEGIFFIHIGFFFIJIIIHGGIGIIIIIIIJIJGGFH###'
!###EEEEEEEDDDDDEDDCDDCCCCCCEDCCCCCCCCCCCDDDDDDEEEEFGEEGGEFEEEEEEEEEEEEEEEEEEEEEFHFFHHHHFGFHJJIIIGHHFFGIIJIIIJHFHJJJ##'
'##EEEEEEEEDDDDDDCCCDCCCCCCCCCCCCCCCCCCCDDDDDDDEEEEEEFFEEEEEEFFEEEEEEEEEFEFEFEEFFFGFGIHIIIIJIIHIGFGHIJJIJGHFGGIII##'
!##FEEEEEDDDCDDDDCCDDCCCCCCCCCCCCCCCCCCCCCDDDCDCCDDEEEEEEEEEEEEEEEFIFEEEEEEEGGFEGEGJIJIIGGGIJHFGIFFIIIHHGFFGJIJJI##'
'##EEEEEDDDDDDDDDDCCCDCDDCCCCCCCCCCCCCCCCCCDDDCCCDCDEEEEEEEEEFEEEEEEEEEFFEEEEEEEFIGFHIIJIIIIGFIHIHFFFFFFGIGFFFHIIJIJJJ##'
!###FEEDDDDDDDDCDDDCDDDCCCCDCDCCCCCCCCCCCCCCCCCCCDDDDEEEEEEEEEEEEEEEEEEGHGEFHFHIHIHIIIFFIHFHFFFFFFFFGFFGFHKJJJJIJ###'
'###EEDDDDDDDDDDDDDDDDDDDDCCDDDDCCCCCCCCCCCCCCCCCCDDDDDDEEEEEEEEEEEEEEEFIGEFHGGHFFGIHFFHHFFFFFFFFFIHFGJIIJJJJJJJJ##'
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'###DDDDDDDDDDDDDDDDDDDDFDDDDDDDDDCCCCCCCCCCCCCDDDDDDDDDDDDDDEEEFFEFFFFSFEFF GIFEEFF IGIIFHFIIHFFFFIFIIHFGIHHIIIIIIJJI##'
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'##DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDCDDDCCDDDDDDDDDDDHDEFGGFEDEGHGFEEEEGFFGFFFFFFGIHIIIIGHGIFFFFFFFFIGFFFFFFFFFFFFFFFFFF###'
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!##DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDEFDGFDDEDDDDEDDDDGGFDEEEEEEEFFFFFFFFFFFFFFFFHFFFFFFFFFFFFFFFFFFFFFFFFFFFFF##'
'##D•DDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDDEEEEFGHDEEDDDDDDDDDDDDDDEFEEFFFFFFFFF#FFFFFFFFFHFFFF#F#F#F############FFF#########'
!########D###########DDD##########FEDD###########################D##DD#####FGF############################!
!##############################################################################################################################'
-------------------------------------------------------------------------------------------------------------------------------
                                                                                                                               1
 CHARLESTON     TX ANT [illegible] FT   RX ANT 500 FT   POWER [illegible] DBM   FREQ  [illegible] MHZ

 382146.0      813518.0  LAT & LON OF SITE

 371000.0      821700.0  LAT & LON OF SW TIC MARK

 384500.0      791900.0  LAT & LON OF NE TIC MARK
                  >     -50.000
 -50.000  >=  A  >     -60.000
 -60.000  >=  B  >     -70.000
 -70.000  >=  C  >     -80.000
 -80.000  >=  D  >     -90.000
 -90.000  >=  E  >    -100.000
-100.000  >=  F  >    -110.000
-110.000  >=  G  >    -120.000
-120.000  >=  H  >    -130.000
-130.000  >=  I  >    -140.000
-140.000  >=  J  >    -150.000
-150.000  >=  K  >    -160.000
-160.000  >=  L  >    -170.000
-170.000  >=  M  >    -180.000
-180.000  >=  N  >    -190.000
-190.000  >=  O  >    -200.000
-200.000  >=  P  >    -210.000
-210.000  >=  Q  >    -220.000
-220.000  >=  R  >    -230.000
-230.000  >=  S  >    -240.000
-240.000  >=  T  >    -250.000
-250.000  >=  U  >    -260.000
-260.000  >=  V  >    -270.000
-270.000  >=  W  >    -280.000
-280.000  >=  X  >    -290.000
-290.000  >=  Y  >    -300.000
-300.000  >=  Z  >    -310.000
-310.000  >=  1  >    -320.000
-320.000  >=  2  >    -330.000
-330.000  >=  3  >    -340.000
-340.000  >=  4  >    -350.000
-350.000  >=  5  >    -360.000
-360.000  >=  6  >    -370.000
-370.000  >=  7  >    -380.000
-380.000  >=  8  >    -390.000
-390.000  >=  9
```
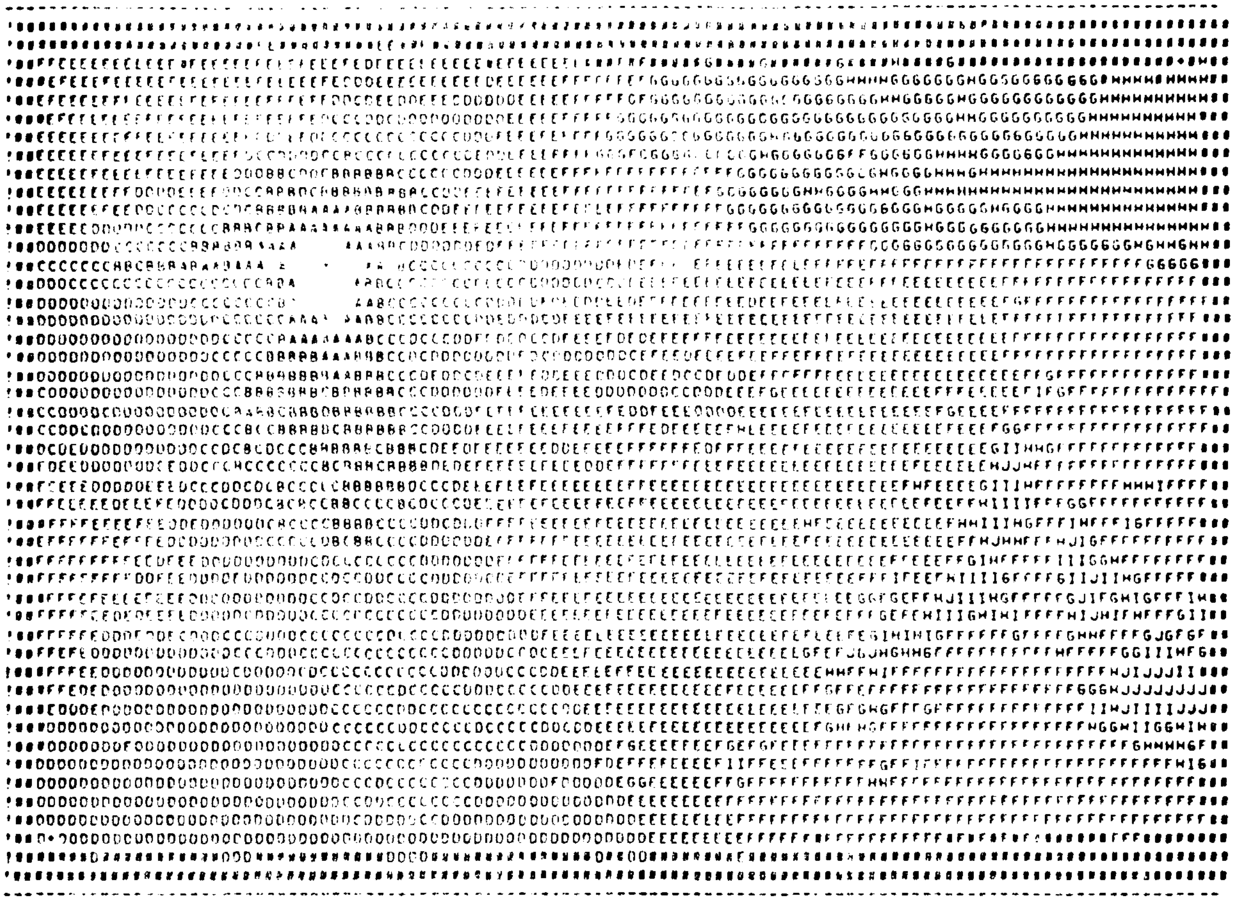
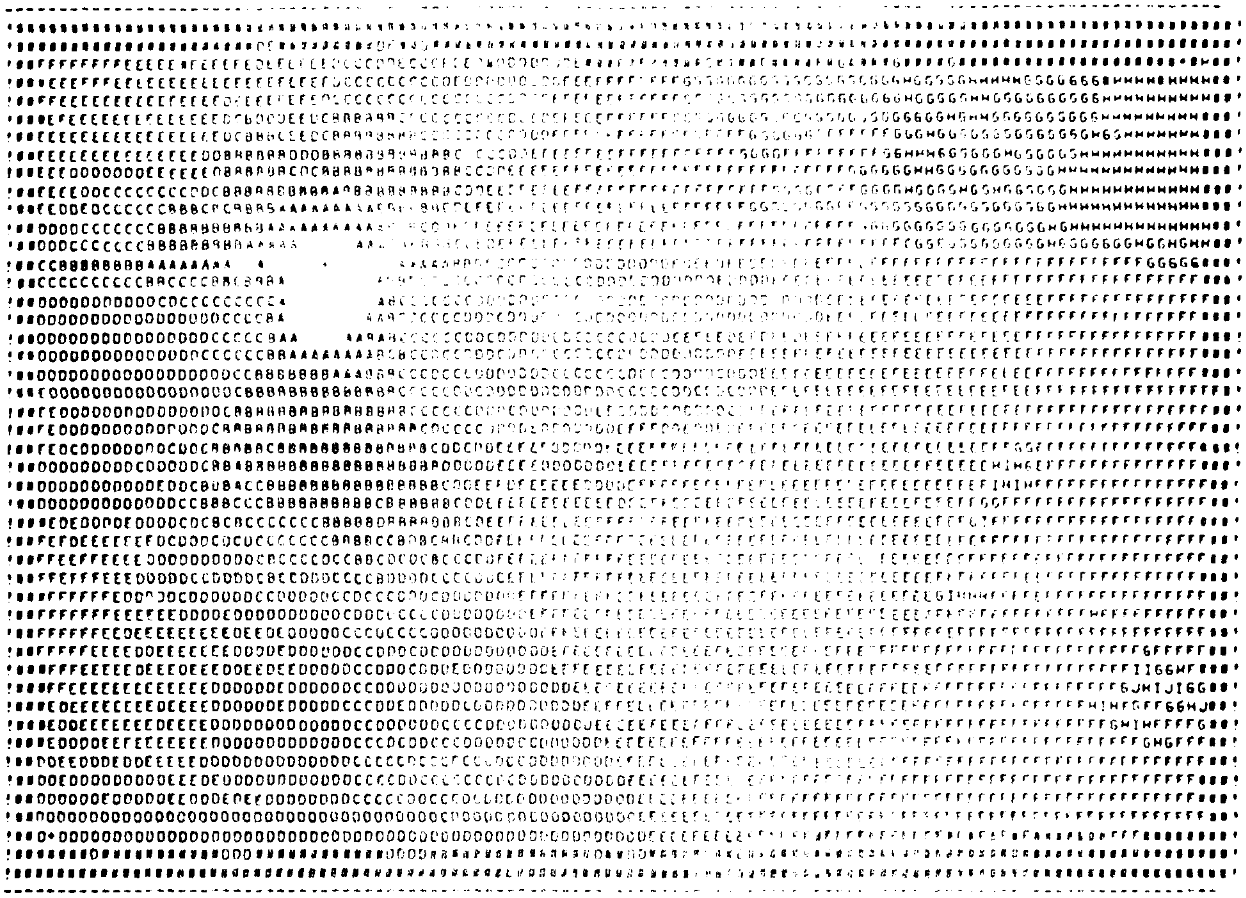
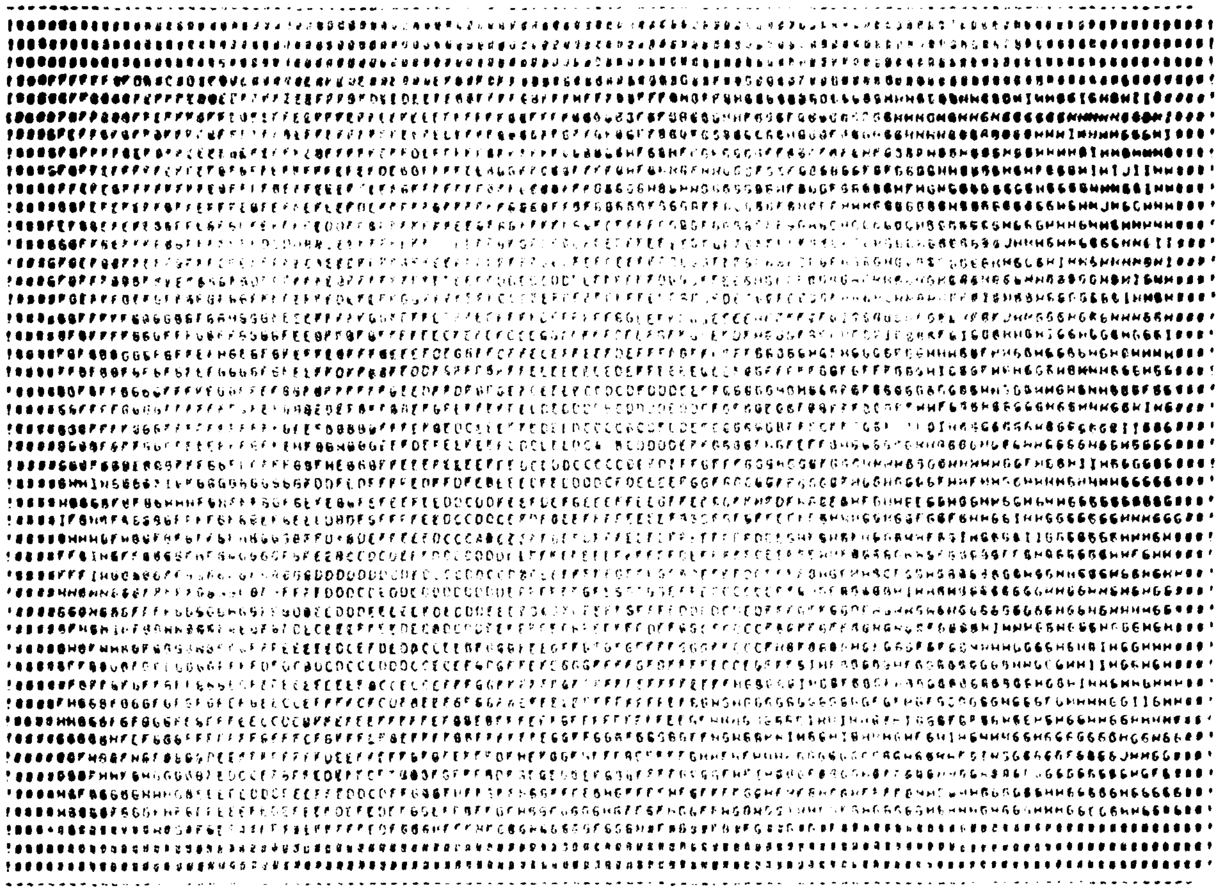

FIGURE C-6



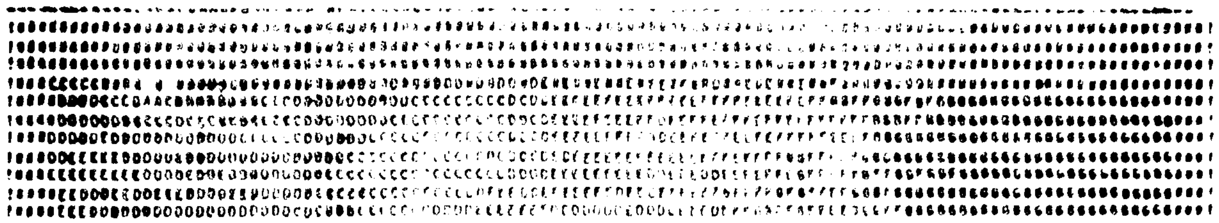
```
CHARLESTON     TX ANT 30 FT   RX ANT 1000 FT   POWER 40 DBM   FREQ 120 MHZ

382146.0     81[illegible]       LAT & LON OF SITE

371030.0     82[illegible]       LAT & LON OF SW TIC MARK

384500.0     791900.0   LAT & LON OF NE TIC MARK
                  >     -50.000
 -50.000 >= A >     -60.000
 -60.000 >= B >     -70.000
 -70.000 >= C >     -80.000
 -80.000 >= D >     -90.000
 -90.000 >= E >    -100.000
-100.000 >= F >    -110.000
-110.000 >= G >    -120.000
-120.000 >= H >    -130.000
-130.000 >= I >    -140.000
-140.000 >= J >    -150.000
-150.000 >= K >    -160.000
-160.000 >= L >    -170.000
-170.000 >= M >    -180.000
-180.000 >= N >    -190.000
-190.000 >= O >    -200.000
-200.000 >= P >    -210.000
-210.000 >= Q >    -220.000
-220.000 >= R >    -230.000
-230.000 >= S >    -240.000
-240.000 >= T >    -250.000
-250.000 >= U >    -260.000
-260.000 >= V >    -270.000
-270.000 >= W >    -280.000
-280.000 >= X >    -290.000
-290.000 >= Y >    -300.000
-300.000 >= Z >    -310.000
-310.000 >= 1 >    -320.000
-320.000 >= 2 >    -330.000
-330.000 >= 3 >    -340.000
-340.000 >= 4 >    -350.000
-350.000 >= 5 >    -360.000
-360.000 >= 6 >    -370.000
-370.000 >= 7 >    -380.000
-380.000 >= 8 >    -390.000
-390.000 >= 9
```



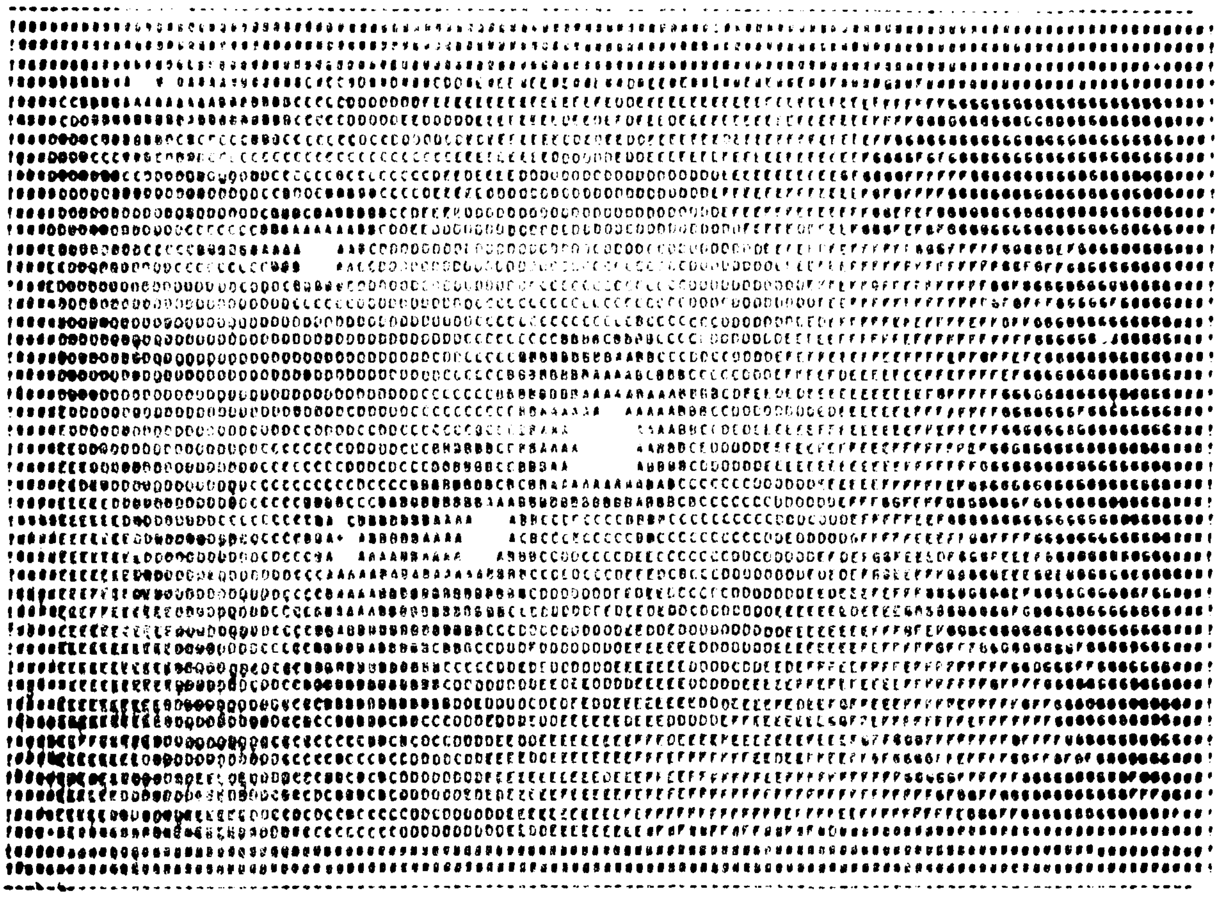
```
                                                                                                              1
  CHARLESTON     TX ANT 20 FT  RX ANT .5 0 FT  POWER 90 DBM  FREQ

  382146.0      813518.0  LAT & LON OF SITE

  371000.0      821700.0  LAT & LON OF SW [illegible] MAP

  384500.0      791900.0  LAT & LON OF NE [illegible] MAP
                     >     -50.000
  -50.000 >= A >    -60.000
  -60.000 >= B >    -70.000
  -70.000 >= C >    -80.000
  -80.000 >= D >    -90.000
  -90.000 >= E >   -100.000
 -100.000 >= F >   -110.000
 -110.000 >= G >   -120.000
 -120.000 >= H >   -130.000
 -130.000 >= I >   -140.000
 -140.000 >= J >   -150.000
 -150.000 >= K >   -160.000
 -160.000 >= L >   -170.000
 -170.000 >= M >   -180.000
 -180.000 >= N >   -190.000
 -190.000 >= O >   -200.000
 -200.000 >= P >   -210.000
 -210.000 >= Q >   -220.000
 -220.000 >= R >   -230.000
 -230.000 >= S >   -240.000
 -240.000 >= T >   -250.000
 -250.000 >= U >   -260.000
 -260.000 >= V >   -270.000
 -270.000 >= W >   -280.000
 -280.000 >= X >   -290.000
 -290.000 >= Y >   -300.000
 -300.000 >= Z >   -310.000
 -310.000 >= 1 >   -320.000
 -320.000 >= 2 >   -330.000
 -330.000 >= 3 >   -340.000
 -340.000 >= 4 >   -350.000
 -350.000 >= 5 >   -360.000
 -360.000 >= 6 >   -370.000
 -370.000 >= 7 >   -380.000
 -380.000 >= 8 >   -390.000
 -390.000 >= 9
```



```
                                                                                        1
MAX OF SURFACE [illegible] SURFACE 3
POWER DENSITY [illegible]

  374709.0     [illegible] OF SITE

  371000.0     [illegible] OF NW [illegible] MARK

  384500.0     [illegible] OF NE [illegible] MARK
                    >      -50.000
   -50.000 >    A  >     -60.000
   -60.000 >    B  >     -70.000
   -70.000 >    C  >     -80.000
   -80.000 >=   D  >     -90.000
   -90.000 >=   E  >    -100.000
  -100.000 >    F  >    -110.000
  -110.000 >=   G  >    -120.000
  -120.000 >=   H  >    -130.000
  -130.000 >=   I  >    -140.000
  -140.000 >=   J  >    -150.000
  -150.000 >=   K  >    -160.000
  -160.000 >=   L  >    -170.000
  -170.000 >=   M  >    -180.000
  -180.000 >=   N  >    -190.000
  -190.000 >=   O  >    -200.000
  -200.000 >=   P  >    -210.000
  -210.000 >    Q  >    -220.000
  -220.000          >    -230.000
  -230.000 >=   S        -240.000
  -240.000 >=   T  >    -250.000
  -250.000 >=   U  >    -260.000
  -260.000 >=   V  >    -270.000
  -270.000 >=   W  >    -280.000
  -280.000 >=   X  >    -290.000
  -290.000 >=   Y  >    -300.000
  -300.000 >=   Z  >    -310.000
  -310.000 >=   1  >    -320.000
   320.000 >=   2  >    -330.000
  -330.000 >=   3  >    -340.000
  -340.000 >=   4  >    -350.000
  -350.000 >=   5  >    -360.000
  -360.000 >=   6  >    -370.000
  -370.000 >=   7  >    -380.000
  -380.000 >    8  .    -390.000
```

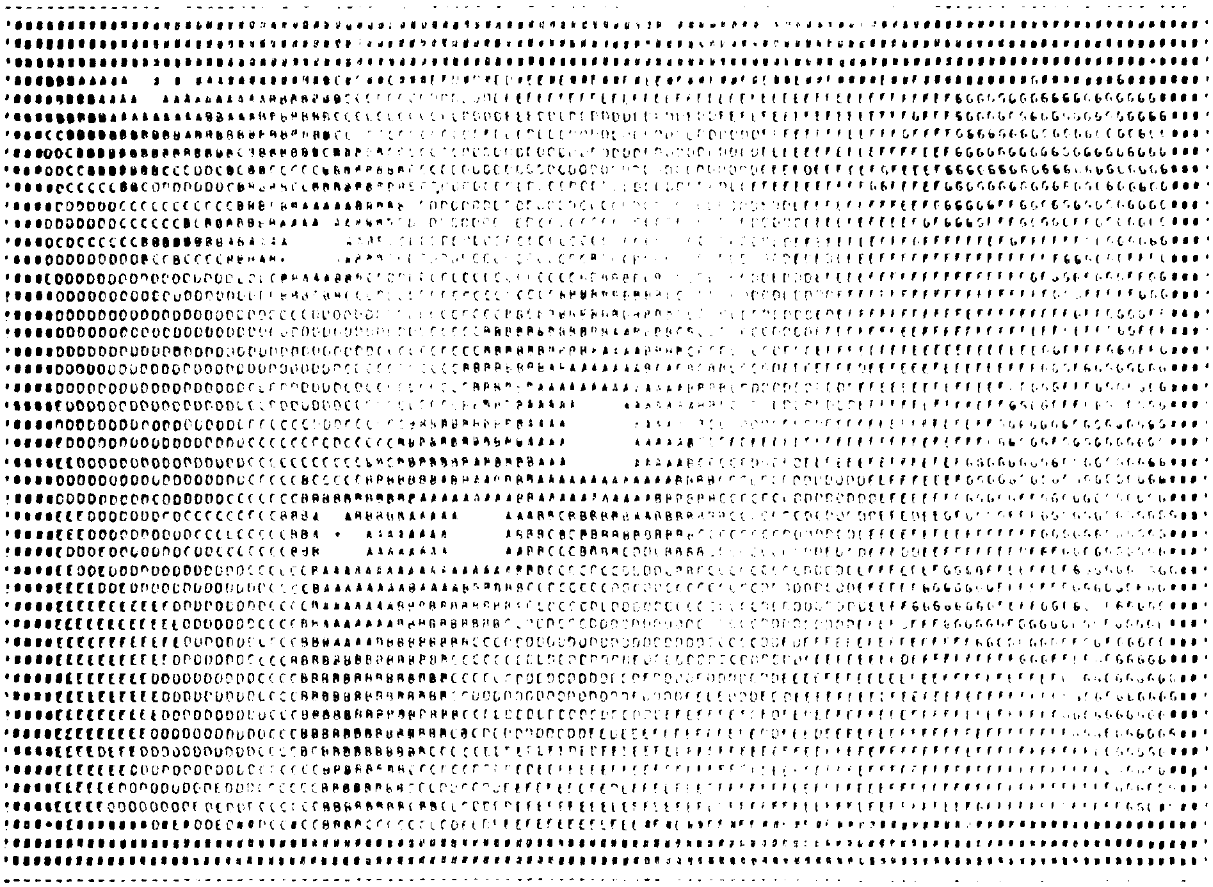


```
                                                                                                    1
MAP OF SURFACE [illegible]
POWER DENSITY [illegible]

   370709.0     [illegible]

   371000.0     [illegible]

   369500.0     [illegible]
                          >   -50.000
   -50.000 >= A >      -60.000
   -60.000 >= B >      -70.000
   -70.000 >= C >      -80.000
   -80.000 >= D >      -90.000
   -90.000 >= E >     -100.000
  -100.000 >= F >     -110.000
  -110.000 >= G >     -120.000
  -120.000 >= H >     -130.000
  -130.000 >= I >     -140.000
  -140.000 >= J >     -150.000
  -150.000 >= K >     -160.000
  -160.000 >= L >     -170.000
  -170.000 >= M >     -180.000
  -180.000 >= N >     -190.000
  -190.000 >= O >     -200.000
  -200.000 >= P >     -210.000
  -210.000 >= Q >     -220.000
  -220.000 >= R >     -230.000
  -230.000 >= S >     -240.000
  -240.000 >= T >     -250.000
  -250.000 >= U >     -260.000
  -260.000 >= V >     -270.000
  -270.000 >= W >     -280.000
  -280.000 >= X >     -290.000
  -290.000 >= Y >     -300.000
  -300.000 >= Z >     -310.000
  -310.000 >= 1 >     -320.000
  -320.000 >= 2 >     -330.000
  -330.000 >= 3 >     -340.000
  -340.000 >= 4 >     -350.000
  -350.000 >= 5 >     -360.000
  -360.000 >= 6 >     -370.000
  -370.000 >= [illegible]
  [illegible]
```

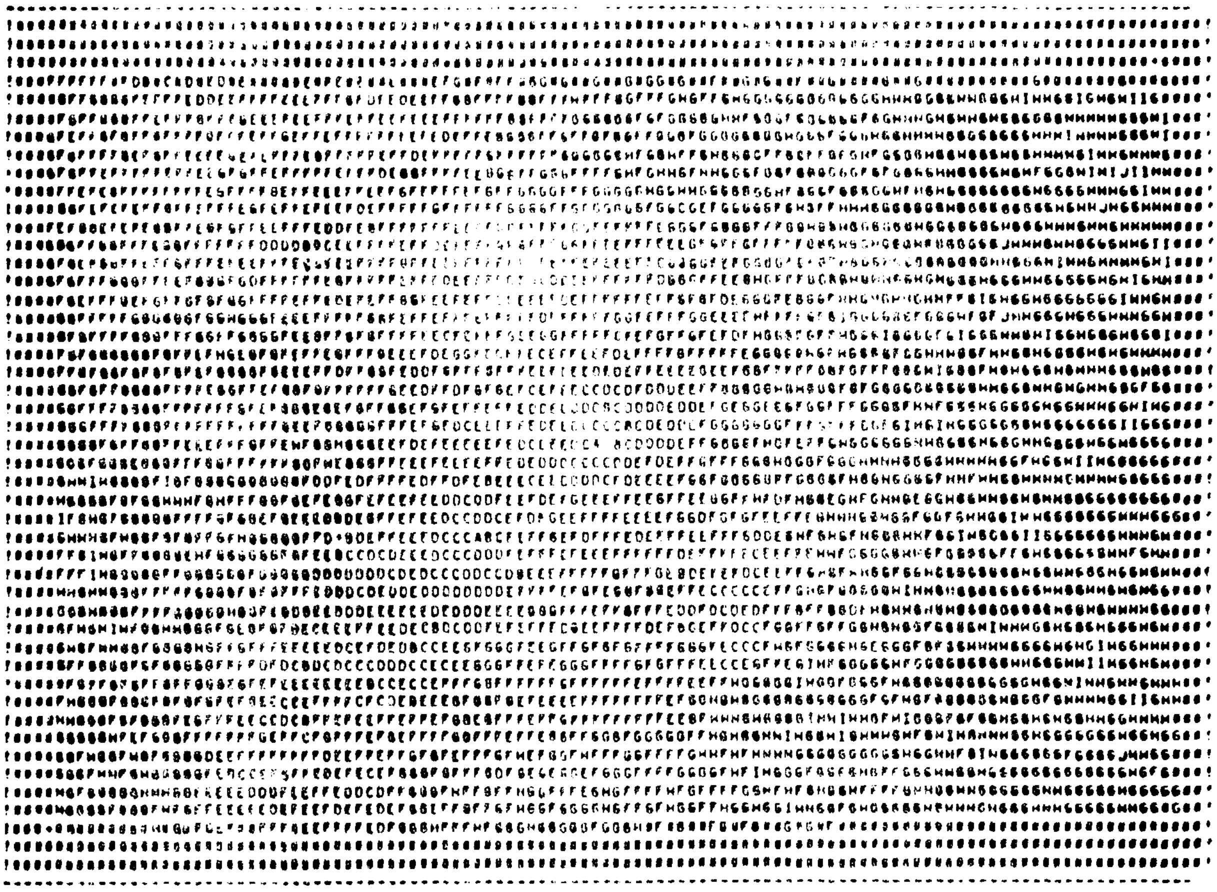


```
MAX OF SURFACE  87  ,  SURFACE  13
POWER DENSITY OF ANNISTON, RAINVILLE, HENDERSON, BECKLEY AND BOLT AT 1000 FT

  379789.9     [illegible]    LAT & LON OF SITE

  373200.0     521700.0  LAT & LON OF SW TIC MARK

  384900.0     771700.0  LAT & LON OF NE TIC MARK
                     >    -50.000
  -50.000 >= A >    -60.000
  -60.000 >= B >    -70.000
  -70.000 >= C >    -80.000
  -80.000 >= D >    -90.000
  -90.000 >= E >   -100.000
 -100.000 >= F >   -110.000
 -110.000 >= G >   -120.000
 -120.000 >= H >   -130.000
 -130.000 >= I >   -140.000
 -140.000 >= J >   -150.000
 -150.000 >= K >   -160.000
 -160.000 >= L >   -170.000
 -170.000 >= M >   -180.000
 -180.000 >= N >   -190.000
 -190.000 >= O >   -200.000
 -200.000 >= P >   -210.000
 -210.000 >= Q >   -220.000
 -220.000 >= R >   -230.000
 -230.000 >= S >   -240.000
 -240.000 >= T >   -250.000
 -250.000 >= U >   -260.000
 -260.000 >= V >   -270.000
 -270.000 >= W >   -280.000
 -280.000 >= X >   -290.000
 -290.000 >= Y >   -300.000
 -300.000 >= Z >   -310.000
 -310.000 >= 1 >   -320.000
 -320.000 >= 2 >   -330.000
 -330.000 >= 3 >   -340.000
 -340.000 >= 4 >   -350.000
 -350.000 >= 5 >   -360.000
 -360.000 >= 6 >   -370.000
 -370.000 >= 7 >   -380.000
 -380.000 >= 8 >   -390.000
```

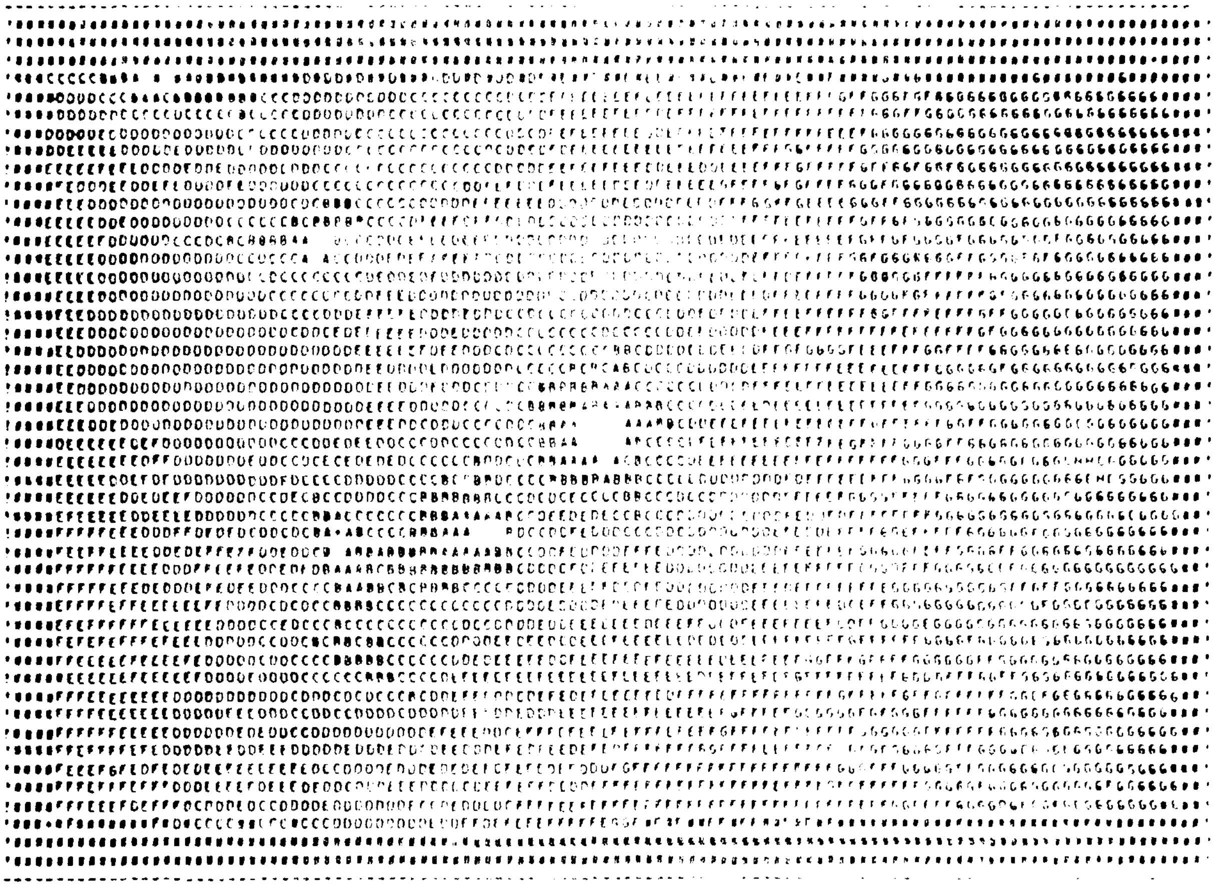
FIGURE C-11



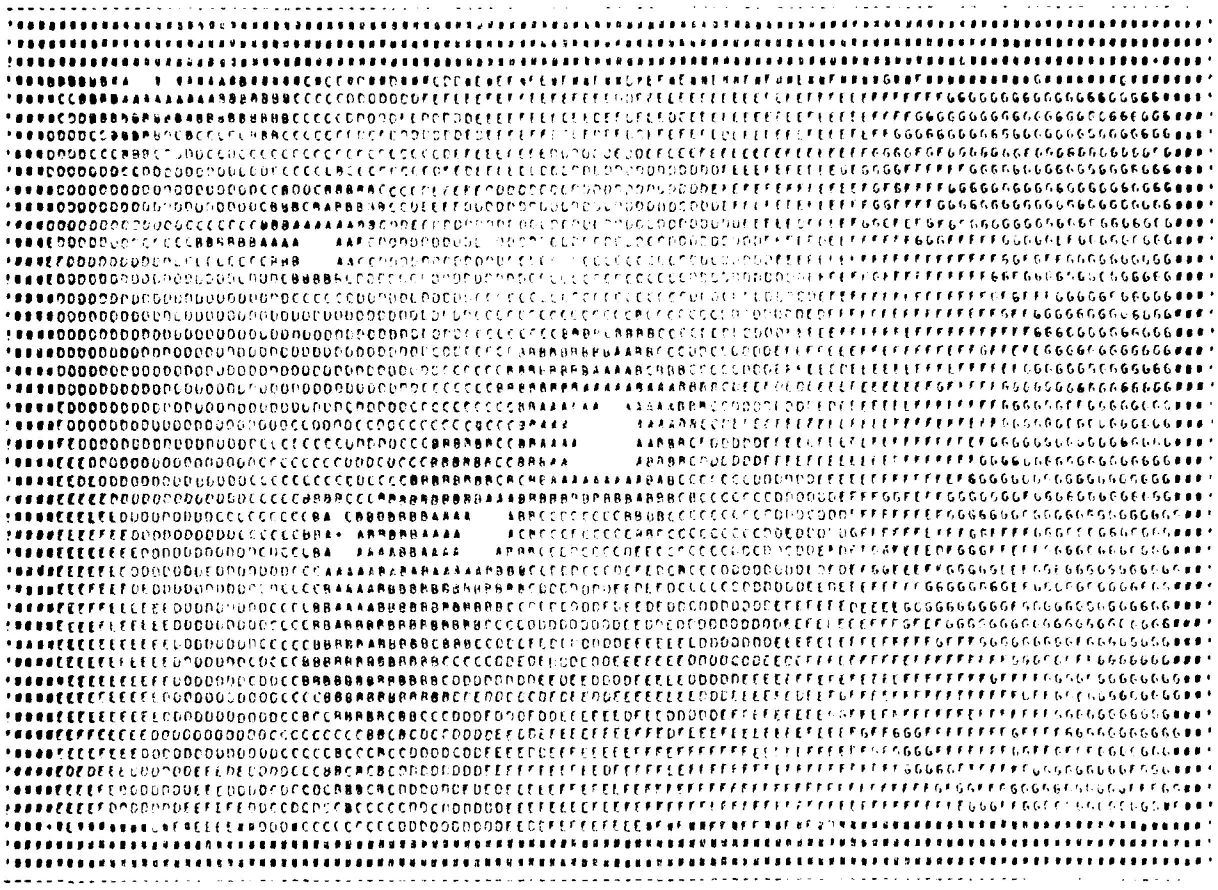
```
MAX OF SURFACE  [illegible]  SURFACE  18
POWER DENSITY OF CHARLESTON, [illegible]

  374739.0     [illegible]

  371000.0     [illegible]

  384500.0     [illegible]
                      >      -50.000
   -50.000 >=  A  >      -60.000
   -60.000 >=  B  >      -70.000
   -70.000 >=  C  >      -80.000
   -80.000 >=  D  >      -90.000
   -90.000 >=  E  >     -100.000
  -100.000 >=  F  >     -110.000
  -110.000 >=  G  >     -120.000
  -120.000 >=  H  >     -130.000
  -130.000 >=  I  >     -140.000
  -140.000 >=  J  >     -150.000
  -150.000 >=  K  >     -160.000
  -160.000 >=  L  >     -170.000
  -170.000 >=  M  >     -180.000
  -180.000 >=  N  >     -190.000
  -190.000 >=  O  >     -200.000
  -200.000 >=  P  >     -210.000
  -210.000 >=  Q  >     -220.000
  -220.000 >=  R  >     -230.000
  -230.000 >=  S  >     -240.000
  -240.000 >=  T  >     -250.000
  -250.000 >=  U  >     -260.000
  -260.000 >=  V  >     -270.000
  -270.000 >=  W  >     -280.000
  -280.000 >=  X  >     -290.000
  -290.000 >=  Y  >     -300.000
  -300.000 >=  Z  >     -310.000
  -310.000 >=  1  >     -320.000
  -320.000 >=  2  >     -330.000
  -330.000 >=  3  >     -340.000
  -340.000 >=  4  >     -350.000
  -350.000 >=  5  >     -360.000
  -360.000 >=  6  >     -370.000
  -370.000 >=  7  >     -380.000
  -380.000 >=  8  >     [illegible]
```



```
                                                                                                    1
MAX OF SURFACE  43  ,  SURFACE   3
POWER DENSITY OF CHARLESTON, BSINELLE, HENDERSON, BECKLEY AND FLAT TOP MTN
AT 10 FT

  374709.0     [illegible]    LAT & LON OF SITE

  371009.0     371700.0   LAT & LON OF SW TIC MARK

  384900.0     771900.0   LAT & LON OF NE TIC MARK
                     >    -50.000
  -50.000 >= A >   -60.000
  -60.000 >= B >   -70.000
  -70.000 >= C >   -80.000
  -80.000 >= D >   -90.000
  -90.000 >= E >  -100.000
 -100.000 >= F >  -110.000
 -110.000 >= G >  -120.000
 -120.000 >= H >  -130.000
 -130.000 >= I >  -140.000
 -140.000 >= J >  -150.000
 -150.000 >= K >  -160.000
 -160.000 >= L >  -170.000
 -170.000 >= M >  -180.000
 -180.000 >= N >  -190.000
 -190.000 >= O >  -200.000
 -200.000 >= P >  -210.000
 -210.000 >= Q >  -220.000
 -220.000 >= R >  -230.000
 -230.000 >= S >  -240.000
 -240.000 >= T >  -250.000
 -250.000 >= U >  -260.000
 -260.000 >= V >  -270.000
 -270.000 >= W >  -280.000
 -280.000 >= X >  -290.000
 -290.000 >= Y >  -300.000
 -300.000 >= Z >  -310.000
 -310.000 >= 1 >  -320.000
 -320.000 >= 2 >  -330.000
 -330.000 >= 3 >  -340.000
 -340.000 >= 4 >  -350.000
 -350.000 >= 5 >  -360.000
 -360.000 >= 6 >  -370.000
 -370.000 >= 7 >  -380.000
 -380.000 >= 8 >  -390.000
 -390.000 >= 9
             #     UNDEFINED VALUE
```

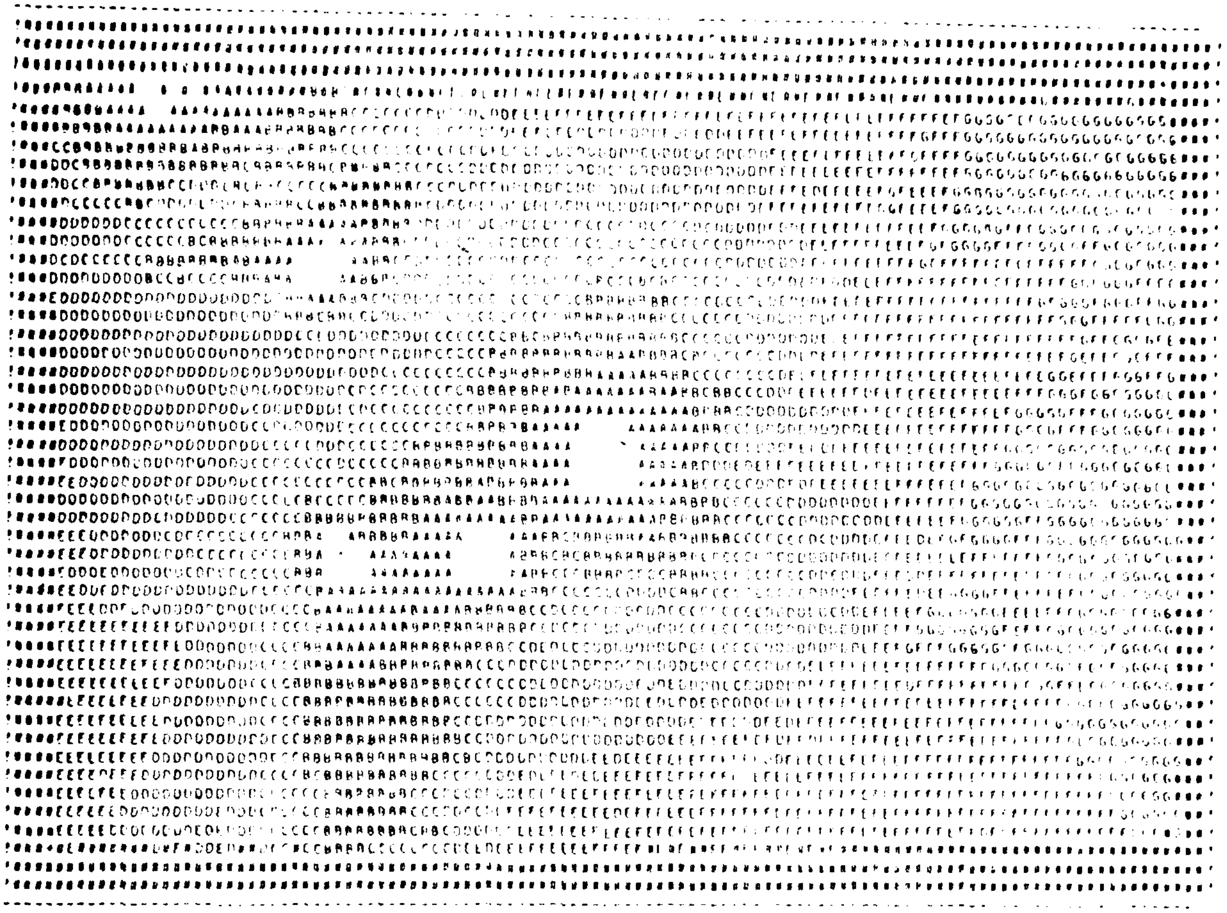


```
MAX OFSURFACE  45   ,  SURFACE    6
POWER DENSITY OF CHARLESTON, RAINELLE, HENDERSON, BECKLEY AN[illegible]
AT 500 FT

  374709.0     413110.0  LAT [illegible]

  371000.0     621700.0  LAT [illegible] TIC MARK

  384500.0     751900.0  LAT & LON [illegible] NE TIC MARK
                      >    -50.000
  -50.000 >   A  >    -60.000
  -60.000 >   B  >    -70.000
  -70.000 >   C  >    -80.000
  -80.000 >   D  >    -90.000
  -90.000 >   E  >   -100.000
 -100.000 >   F  >   -110.000
 -110.000 >   G  >   -120.000
 -120.000 >   H  >   -130.000
 -130.000 >   I  >   -140.000
 -140.000 >   J  >   -150.000
 -150.000 >   K  >   -160.000
 -160.000 >   L  >   -170.000
 -170.000 >   M  >   -180.000
 -180.000 >   N  >   -190.000
 -190.000 >   O  >   -200.000
 -200.000 >   P  >   -210.000
 -210.000 >   Q  >   -220.000
 -220.000 >   R  >   -230.000
 -230.000 >   S  >   -240.000
 -240.000 >   T  >   -250.000
 -250.000 >   U  >   -260.000
 -260.000 >   V  >   -270.000
 -270.000 >   W  >   -280.000
 -280.000 >   X  >   -290.000
 -290.000 >   Y  >   -300.000
 -300.000 >   Z  >   -310.000
 -310.000 >   1  >   -320.000
 -320.000 >   2  >   -330.000
 -330.000 >   3  >   -340.000
 -340.000 >   4  >   -350.000
 -350.000 >   5  >   -360.000
 -360.000 >   6  >   -370.000
 -370.000 >   7  >   -380.000
 -380.000 >   8  >   [illegible]
```



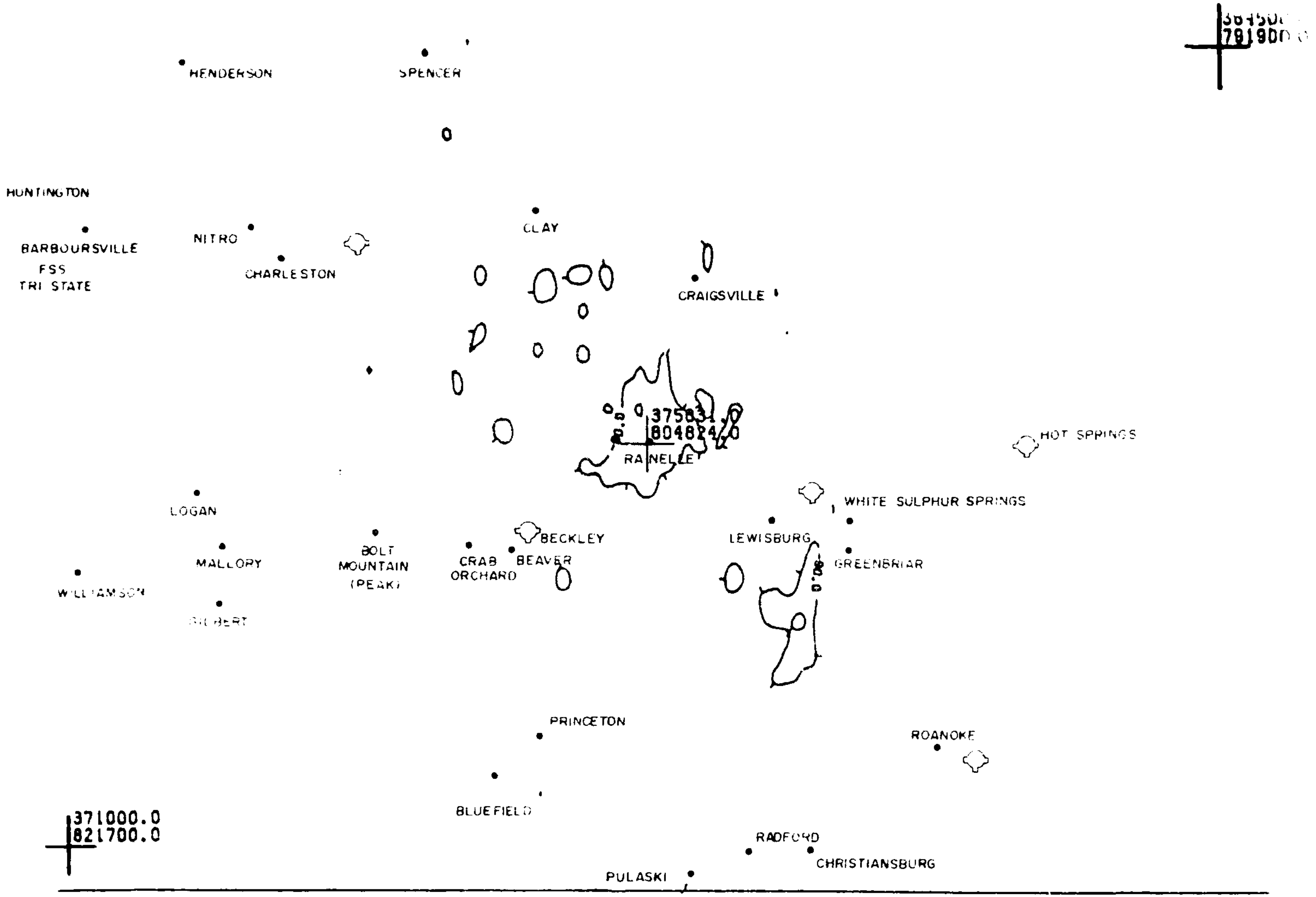
```
MAX OFSURFACE [illegible] , [illegible] SURFACE [illegible]
POWER DENSITY OF CHARLESTON, PATRIOT[illegible], HENDERSON, BECKLEY AND FLAT TOP MTN
AT 1000 FT

   374709.0     [illegible]   LAT & LON OF SITE

   371000.0     [illegible]   LAT & LON OF [illegible] MARK

   388500.0     [illegible]   LAT & LON OF NE [illegible] MARK
                         -50.000
  -50.000 >   A >    -60.000
  -60.000 >=  B >    -70.000
  -70.000 >=  C >    -80.000
  -80.000 >=  D >    -90.000
  -90.000 >=  E >   -100.000
 -100.000 >=  F >   -110.000
 -110.000 >=  G >   -120.000
 -120.000 >=  H >   -130.000
 -130.000 >=  I >   -140.000
 -140.000 >=  J >   -150.000
 -150.000 >=  K >   -160.000
 -160.000 >=  L >   -170.000
 -170.000 >=  M >   -180.000
 -180.000 >=  N >   -190.000
 -190.000 >=  O >   -200.000
 -200.000 >=  P >   -210.000
 -210.000 >=  Q >   -220.000
 -220.000 >=  R >   -230.000
 -230.000 >=  S >   -240.000
 -240.000 >=  T >   -250.000
 -250.000 >=  U >   -260.000
 -260.000 >=  V >   -270.000
 -270.000 >=  W >   -280.000
 -280.000 >=  X >   -290.000
 -290.000 >=  Y >   -300.000
 -300.000 >=  Z >   -310.000
 -310.000 >=  1 >   -320.000
 -320.000 >=  2 >   -330.000
 -330.000 >=  3 >   -340.000
 -340.000 >=  4 >   -350.000
 -350.000 >=  5 >   -360.000
 -360.000 >=  6 >   -370.000
 -370.000 >=  7 >   -380.000
 -380.000 >=  8 >   -390.000
 [illegible]  9
```

FIGURE C-15



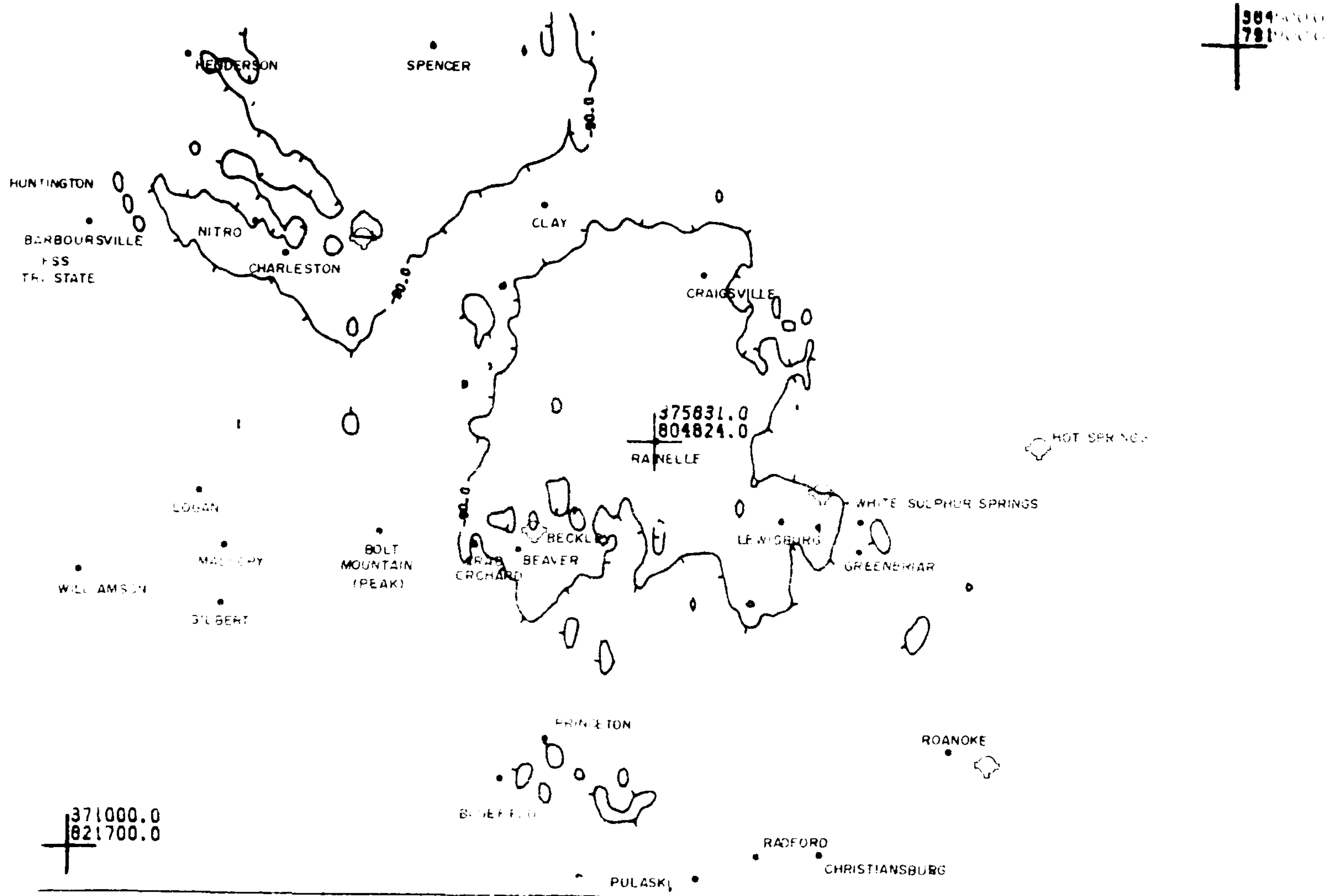
```
MAX OFSURFACE  [illegible] ,  SURFACE  [illegible]
POWER DENSITY OF CHARLESTON, [illegible], [illegible], [illegible] AND [illegible]
AT 1500 FT

  374709.0     3[illegible]     [illegible]

  371000.0     821[illegible]   LOCATION OF [illegible] MARK

  366500.0     791900.0   LOCATION OF [illegible]
                 >     50.000
  -50.000 >  A >    -60.000
  -60.000 >= B >    -70.000
  -70.000 >  C >    -80.000
  -80.000 >  D >    -90.000
  -90.000 >= E >   -100.000
 -100.000 >= F >   -110.000
 -110.000 >  G >   -120.000
 -120.000 >= H >   -130.000
 -130.000 >= I >   -140.000
 -140.000 >  J >   -150.000
 -150.000 >= K >   -160.000
 -160.000 >= L >   -170.000
 -170.000 >  M >   -180.000
 -180.000 >  N >   -190.000
 -190.000 >  O >   -200.000
 -200.000 >= P >   -210.000
 -210.000 >  Q >   -220.000
 -220.000 >  R >   -230.000
 -230.000 >= S >   -240.000
 -240.000 >= T >   -250.000
 -250.000 >= U >   -260.000
 -260.000 >= V >   -270.000
 -270.000 >= W >   -280.000
 -280.000 >= X >   -290.000
 -290.000 >= Y >   -300.000
 -300.000 >  Z >   [illegible]
 -310.000 >  1 >   -320.[illegible]
 -320.000 >    >   -330.[illegible]
 -330.000 >  3     [illegible]
 -340.000 >  4 >   [illegible]
 -350.000 [illegible]
 -360.[illegible]
  [illegible]
  [illegible]
```

FIGURE C-36

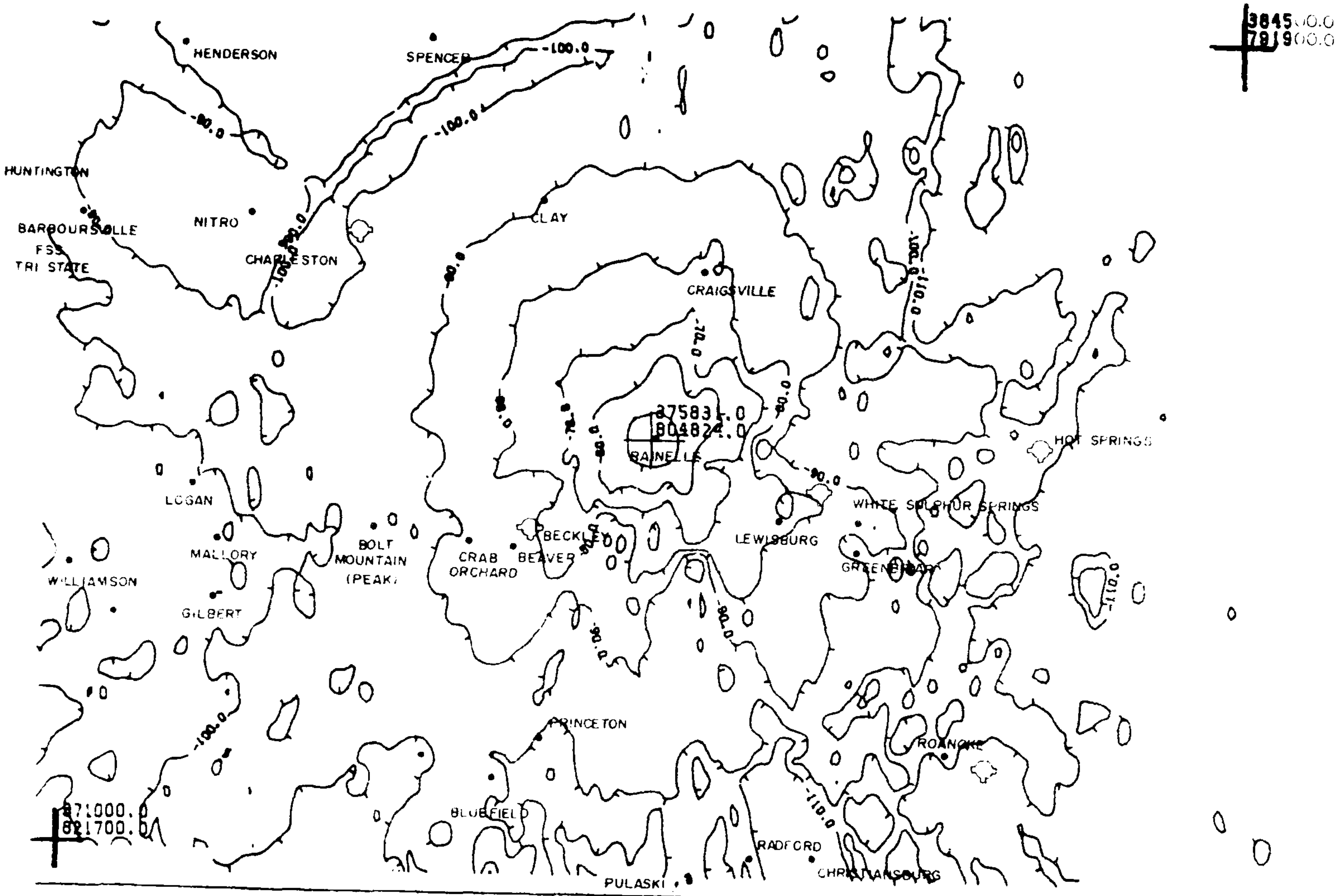

384500.0
791900.0
HENDERSON
SPENCER
HUNTINGTON
BARBOURSVILLE
FSS
TRI STATE
NITRO
CHARLESTON
CLAY
CRAIGSVILLE
375831.0
804824.0
RAINELLE
HOT SPRINGS
WHITE SULPHUR SPRINGS
LEWISBURG
GREENBRIAR
-90.0
LOGAN
MALLORY
WILLIAMSON
GILBERT
BOLT
MOUNTAIN
(PEAK)
CRAB
ORCHARD
BEAVER
BECKLEY
PRINCETON
BLUEFIELD
ROANOKE
RADFORD
CHRISTIANSBURG
PULASKI
371000.0
821700.0

RAINELLE WVA TX ANT 20 FT RX ANT 10 FT POWER 40 DBM FREQ 120 MHZ

[illegible]-17

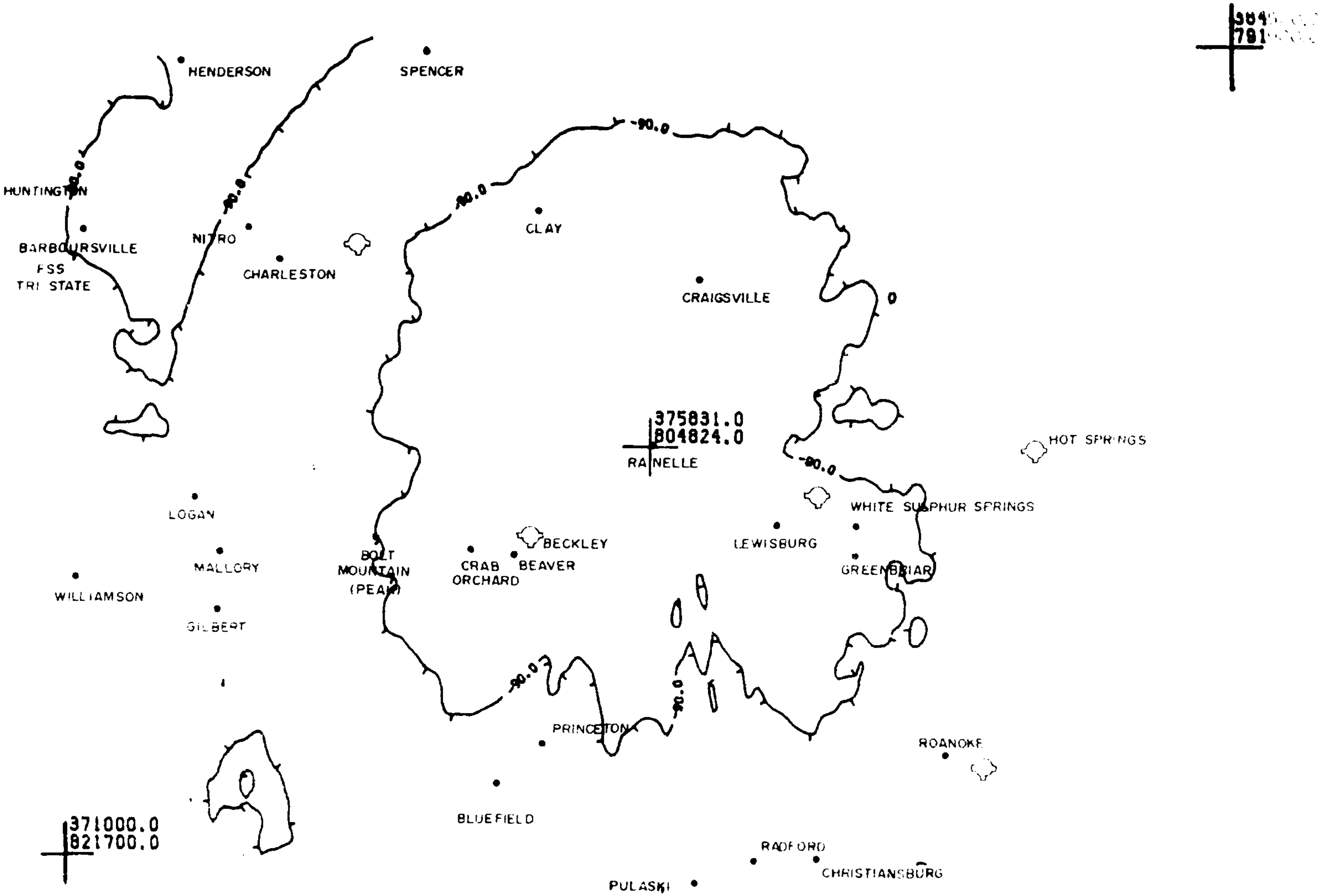

HENDERSON
SPENCER
HUNTINGTON
BARBOURSVILLE
FSS
TRI STATE
NITRO
CHARLESTON
CLAY
CRAIGSVILLE
90.0
90.0
90.0
375831.0
804824.0
RAINELLE
HOT SPRINGS
WHITE SULPHUR SPRINGS
LEWISBURG
GREENBRIAR
BECKLEY
BEAVER
GRANDVIEW
ORCHARD
BOLT
MOUNTAIN
(PEAK)
LOGAN
MALLORY
WILLIAMSON
GILBERT
PRINCETON
BLUEFIELD
ROANOKE
RADFORD
CHRISTIANSBURG
PULASKI
371000.0
821700.0
384
781

RAINELLE WVA TX ANT 20 FT RX ANT 500 FT PØWER 40 DBM FREQ 120 MHZ


3845000.0
781900.0
HENDERSON
SPENCER
-100.0
-90.0
-100.0
HUNTINGTON
BARBOURSVILLE
NITRO
FSS
TRI STATE
CHARLESTON
-100.0
-90.0
CLAY
-90.0
CRAIGSVILLE
-110.0
-100.0
-70.0
-80.0
375831.0
804824.0
RAINELLE
-80.0
HOT SPRINGS
-90.0
WHITE SULPHUR SPRINGS
LOGAN
MALLORY
BOLT
MOUNTAIN
(PEAK)
CRAB
ORCHARD
BEAVER
BECKLEY
LEWISBURG
GREENBRIAR
-110.0
WILLIAMSON
GILBERT
-90.0
-90.0
-100.0
PRINCETON
ROANOKE
BLUEFIELD
-110.0
RADFORD
PULASKI
CHRISTIANSBURG
371000.0
821700.0

RAINELLE WVA TX ANT 20 FT RX ANT 1000 VERTICAL PØL
TX ANT GAIN 0 DBI PØWER 40 DBM FREQ 120 MHZ

Figure C-19


HENDERSON
SPENCER
HUNTINGTON
BARBOURSVILLE
FSS
TRI STATE
NITRO
CHARLESTON
CLAY
CRAIGSVILLE
-90.0
-90.0
-90.0
-90.0
-90.0
-90.0
0
375831.0
804824.0
RAINELLE
HOT SPRINGS
WHITE SULPHUR SPRINGS
LEWISBURG
GREENBRIAR
LOGAN
MALLORY
WILLIAMSON
GILBERT
BOLT
MOUNTAIN
(PEAK)
CRAB
ORCHARD
BEAVER
BECKLEY
PRINCETON
BLUEFIELD
ROANOKE
RADFORD
CHRISTIANSBURG
PULASKI
371000.0
821700.0
3841
791

RAINELLE WVA TX ANT 20 FT RX ANT 1500 FT PØWER 40 DBM FREQ 120 MH

Figure C-20

APPENDIX D

ANTENNA TEST DATA

Characteristics of four modern antennas, listed below, are included herein for possible facility improvement.

1. Decibel Products Model DB-224 VHF Gain Antenna
2. TACO Model Y-102B-130 VHF Directional Yagi Antenna
3. TACO Model D-2261A-1 Omnidirectional VHF Antenna
4. TACO Model D-2276 Omnidirectional VHF Antenna

The characteristics of the high gain antennas, 1 and 2 above, were measured at NAFEC as reported in "Test and Evaluation of Air/Ground Communications Antennas" by James Coyle, June 1978, Report No. FAA-NA-77-39. Appendices G and V of the NAFEC report, which provide the test results, are included herein.

APPENDIX G

DECIBEL PRODUCTS DB-224 VHF GAIN ANTENNA

The DB-224 antenna shown in figure G-1 is a vertically polarized omnidirectional or directional gain antenna that was designed to operate with a center frequency of 127 MHz. This antenna was manufactured by Decibel Products, Inc., Dallas, Texas, weighs 35 pounds, is 23 feet 9 inches long, and cost $230.00. Due to its size, the DB-224 antenna was shipped to NAFEC in two 12-foot sections for ease of handling with each section consisting of two folded dipole elements and a cable harness. An omnidirectional radiation pattern is obtained with this antenna when all four dipole elements are evenly spaced every 90° around the mast. When all four dipoles are aligned on one side of the mast this antenna has directional characteristics and is designated as a DB-224E antenna.

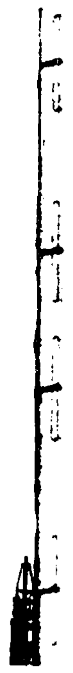


FIGURE G-1. DB-224 VHF GAIN ANTENNA

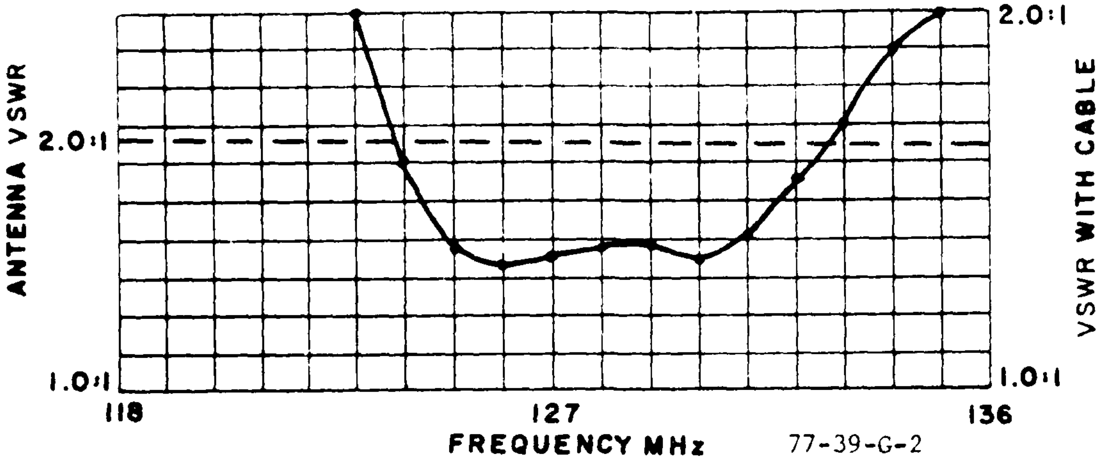


FIGURE G-2. DB-224 GAIN ANTENNA

VSWR measurements for the DB-224 antenna are shown in figure G-2. The numbers on the left side of the graph represent VSWR values at the antenna terminal and the numbers on the right side of the graph represent VSWR values with a 50 foot length of RG-214 coaxial cable between the antenna and the slotted line.

Figure G-3 is the vertical radiation pattern for the DB-224E antenna at 127 MHz. This vertical pattern shows the peak of the main beam to have a slight downward tilt and a 17° beamwidth. Figure G-4 is the horizontal radiation pattern for the DB-224E antenna which shows the offset directional characteristics when the four dipole elements are aligned on one side of the mast.

The gain of the DB-224E antenna measured 6 dB above the standard gain antenna (+6 dBd or +8 dBi) at 127 MHz on the peak of the main beam, as shown by the standard gain antenna dots on the radiation patterns. In the omnidirectional configuration, the antenna measured 3 dB above the standard gain dipole.

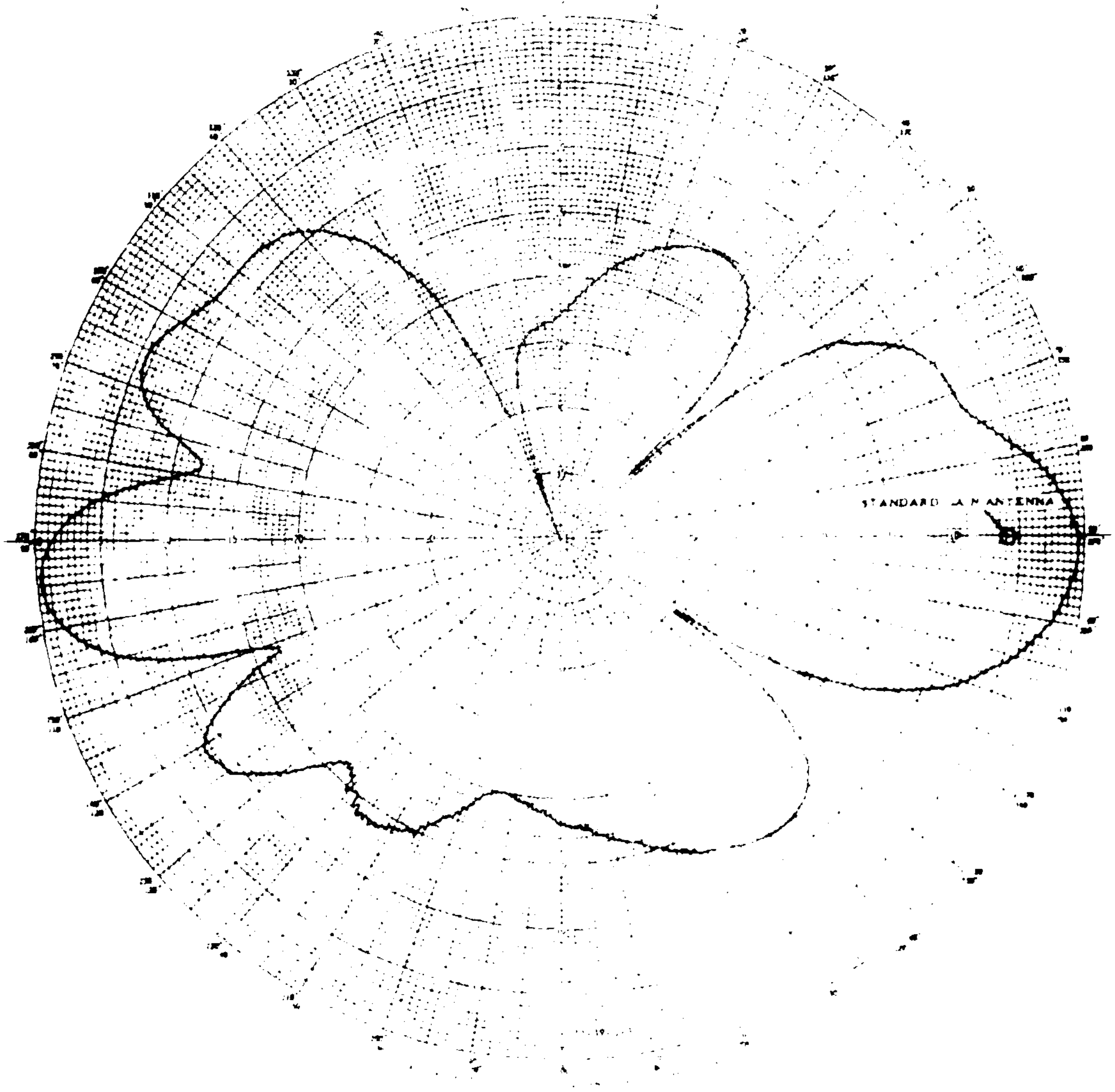


FIGURE G-3. DB-224E VERTICAL RADIATION PATTERN

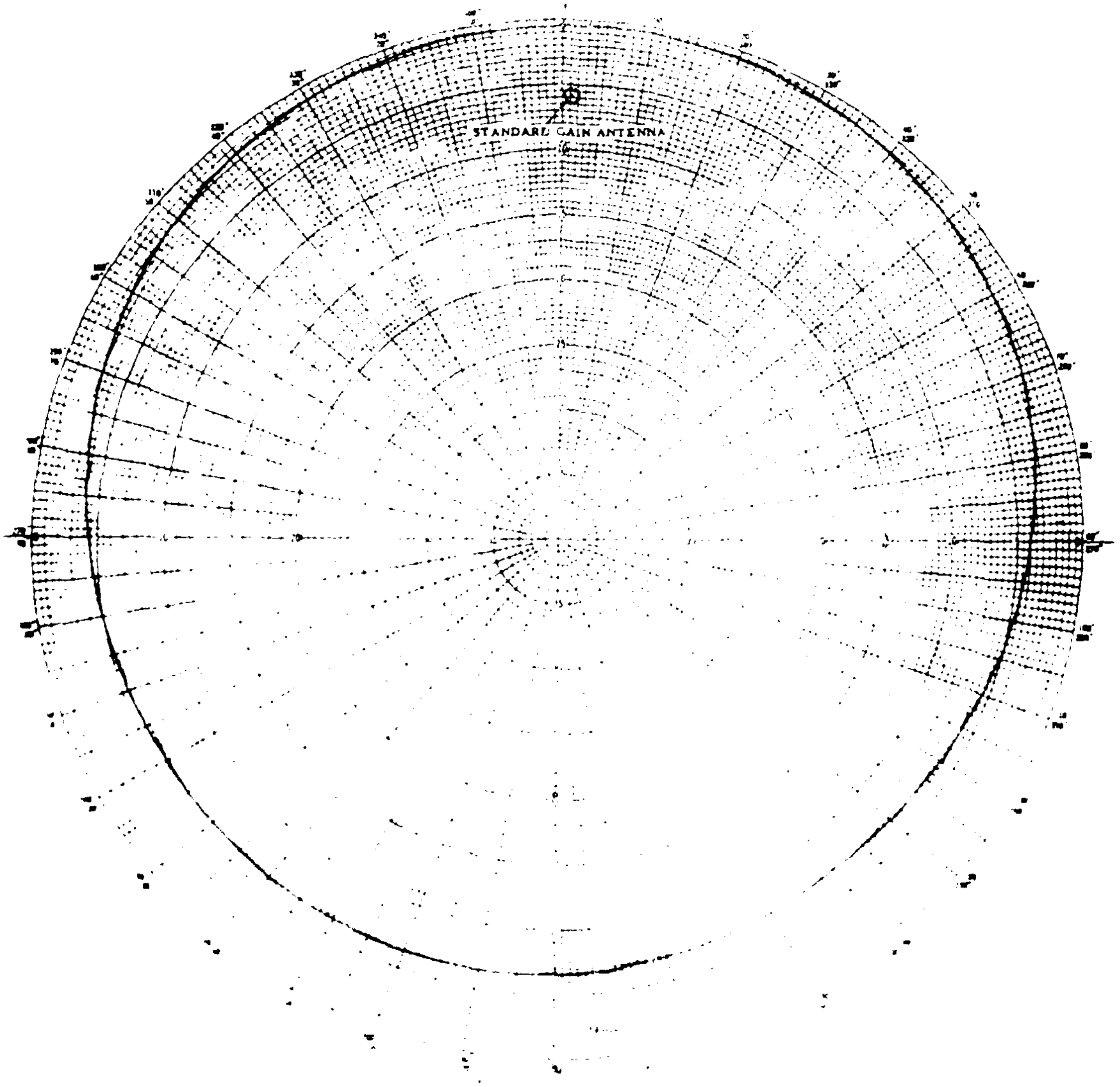


FIGURE G-4. DB-224E HORIZONTAL RADIATION PATTERN

APPENDIX V

TACO Y-102B-130 VHF DIRECTIONAL YAGI ANTENNA

The Y-102B-130 antennas shown in figure V-1 are vertically polarized 10-element directional YAGI antennas that were designed to operate across the VHF A/G communication frequency band of 118 to 136 MHz. These antennas were manufactured by the Technical Appliance Corporation, Sherburne, New York, and cost $202.00 each, weigh 12 pounds each and are 103-inches long and 50 inches high. The antennas are shown vertically stacked 10 feet apart and connected together with a stacking harness to permit increased gain and skewing measurements.

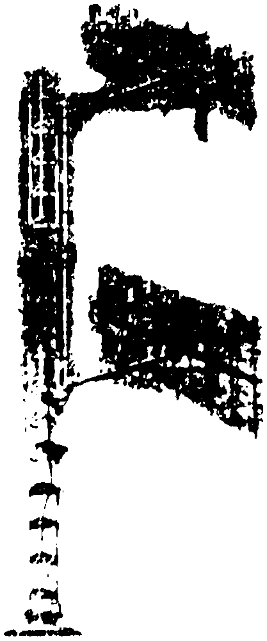


FIGURE V-1. Y-102B-130 YAGI ANTENNAS

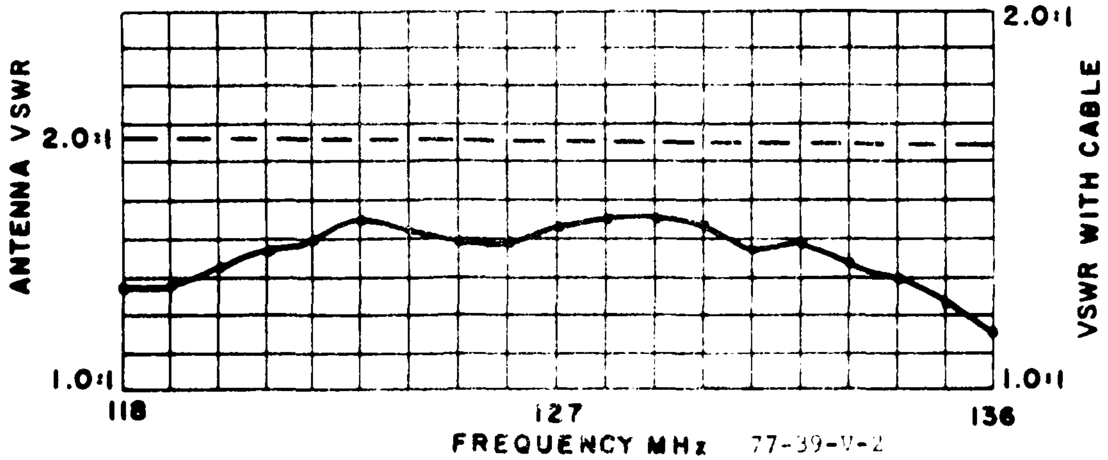


FIGURE V-2. TACO-Y-102B-136 DIRECTIONAL YAGI ANTENNA

VSWR measurements for the antenna are shown in figure V-2. The numbers on the left side of the graph represent VSWR values at the antenna terminal and the numbers at the right side of the graph represent VSWR values with 50 foot of RG-214 coaxial cable between the antenna and the slotted line.

The single antenna vertical radiation pattern at 136 MHz, in figure V-3, shows a 50° vertical beamwidth. The single antenna horizontal radiation pattern in figure V-4 shows a horizontal beamwidth of 62°. Figure V-5 is the horizontal radiation pattern for two antennas vertically stacked and skewed 0° which shows the horizontal beamwidth was reduced from 62° to 54° by vertical stacking. Figure V-6 shows the horizontal radiation pattern at 136 MHz when the antennas are skewed 90° and figure V-7 shows the horizontal radiation pattern when the antennas were skewed 180°.

The gain of the single Yagi antenna measured 12 dB above the standard gain dipole (+12 dBd or +14 dBi) at 136 MHz as shown by the standard gain antenna dots on the radiation patterns. The antenna gains increased 3 dB when stacked and skewed 0° and decreased 3 dB when stacked and skewed 180°.

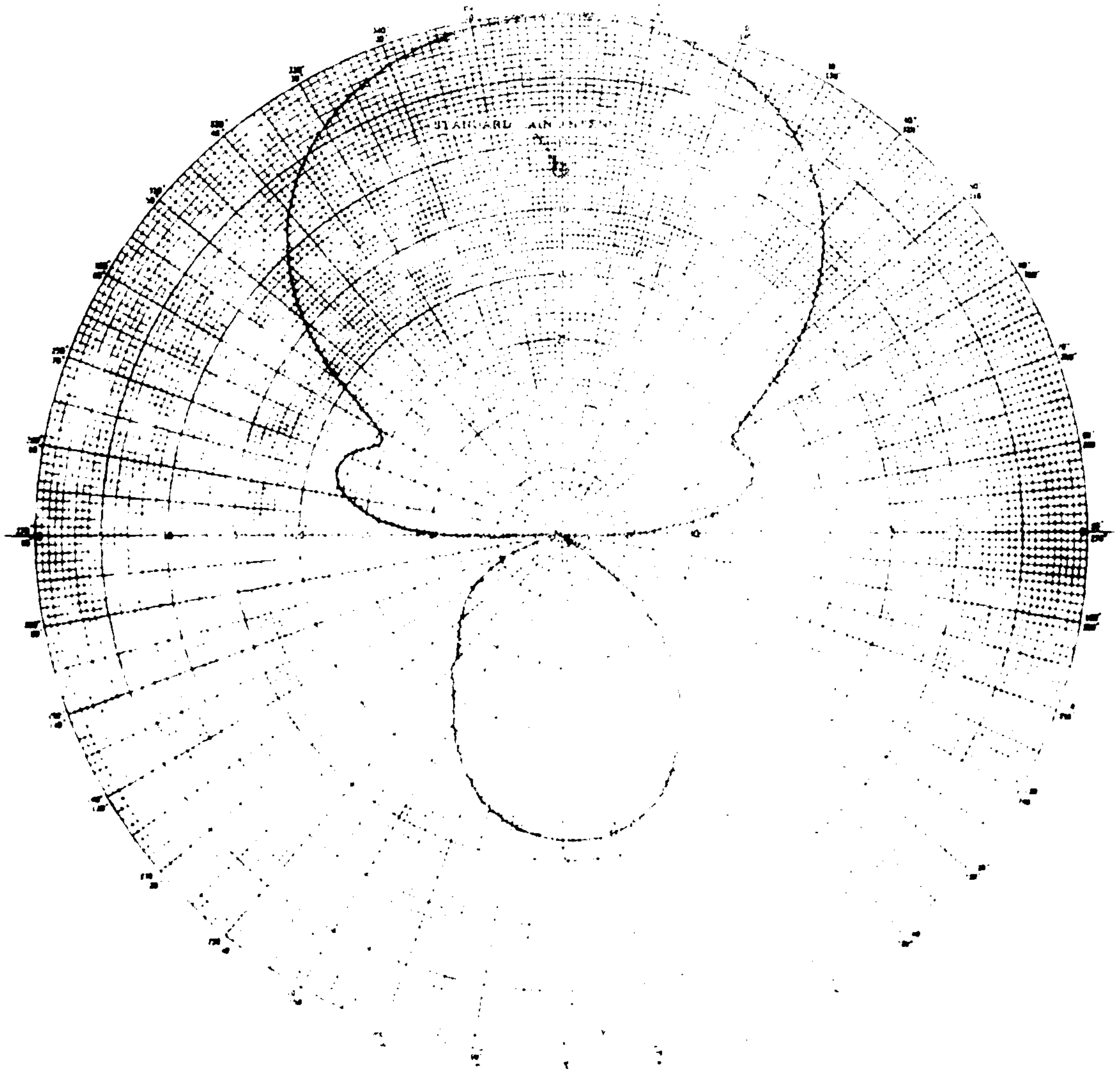


FIGURE V-3. Y-102B-130 VERTICAL RADIATION PATTERN

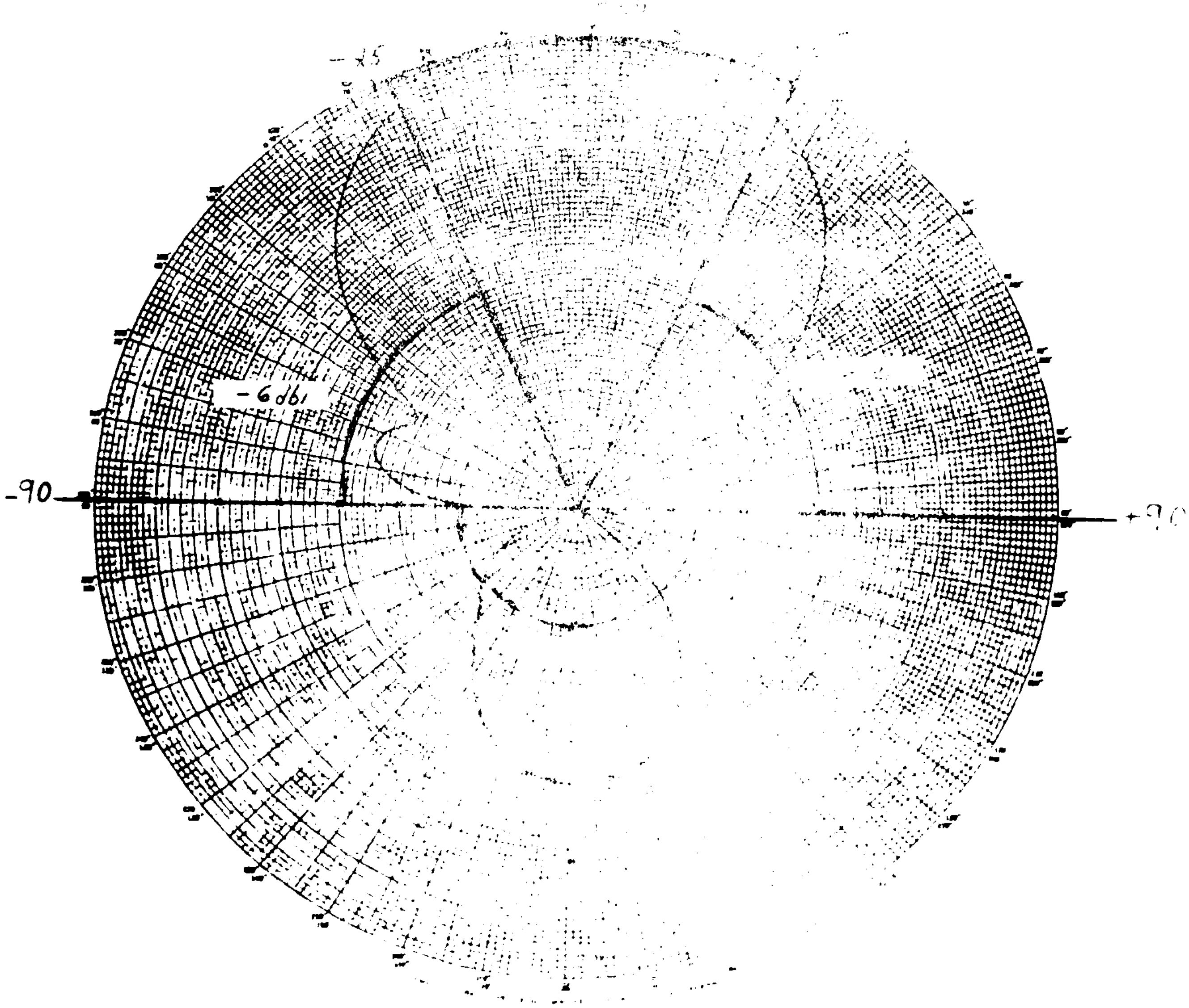


FIGURE V-3. [illegible]

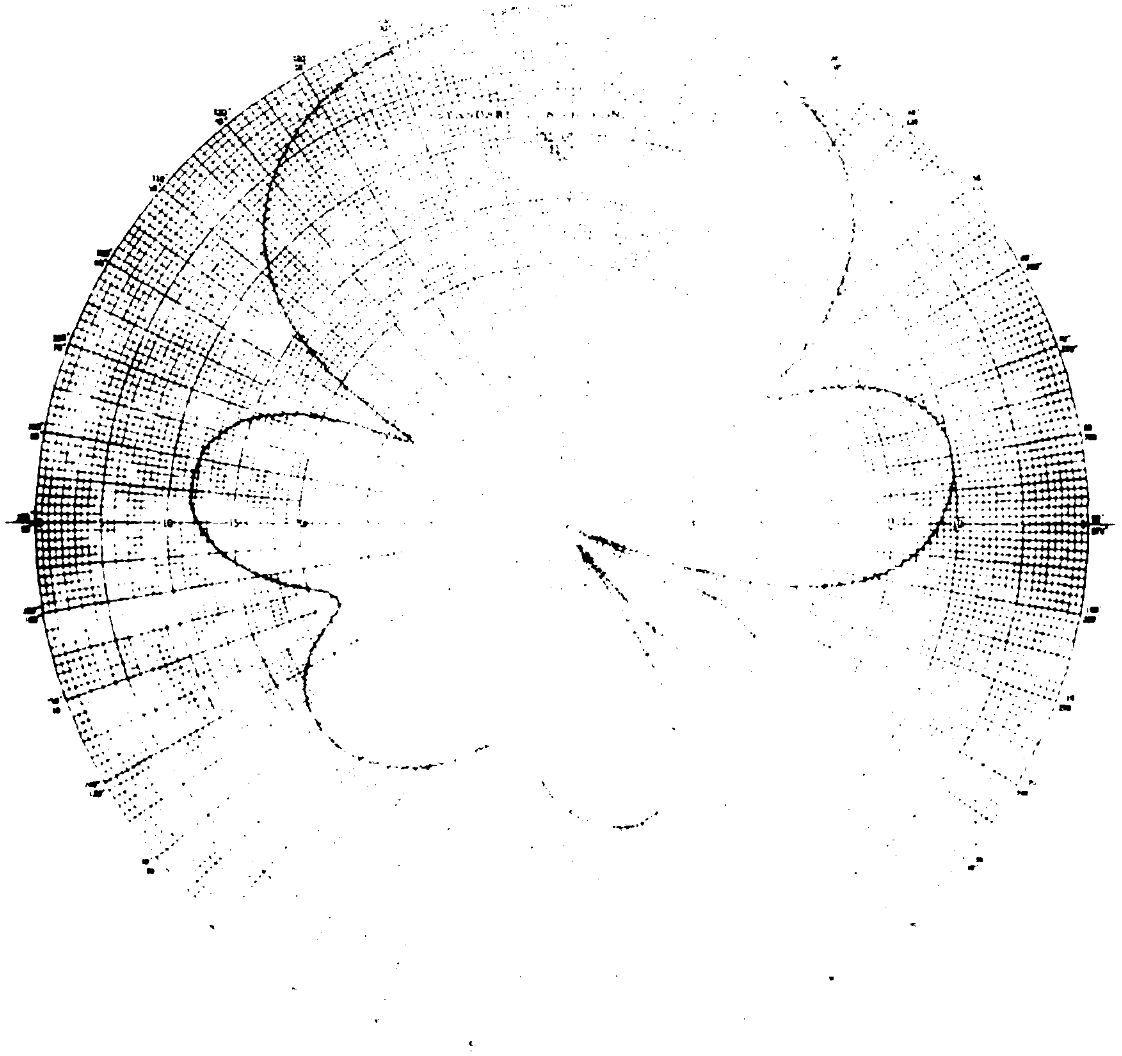


FIGURE V-4. [illegible] PATTERN

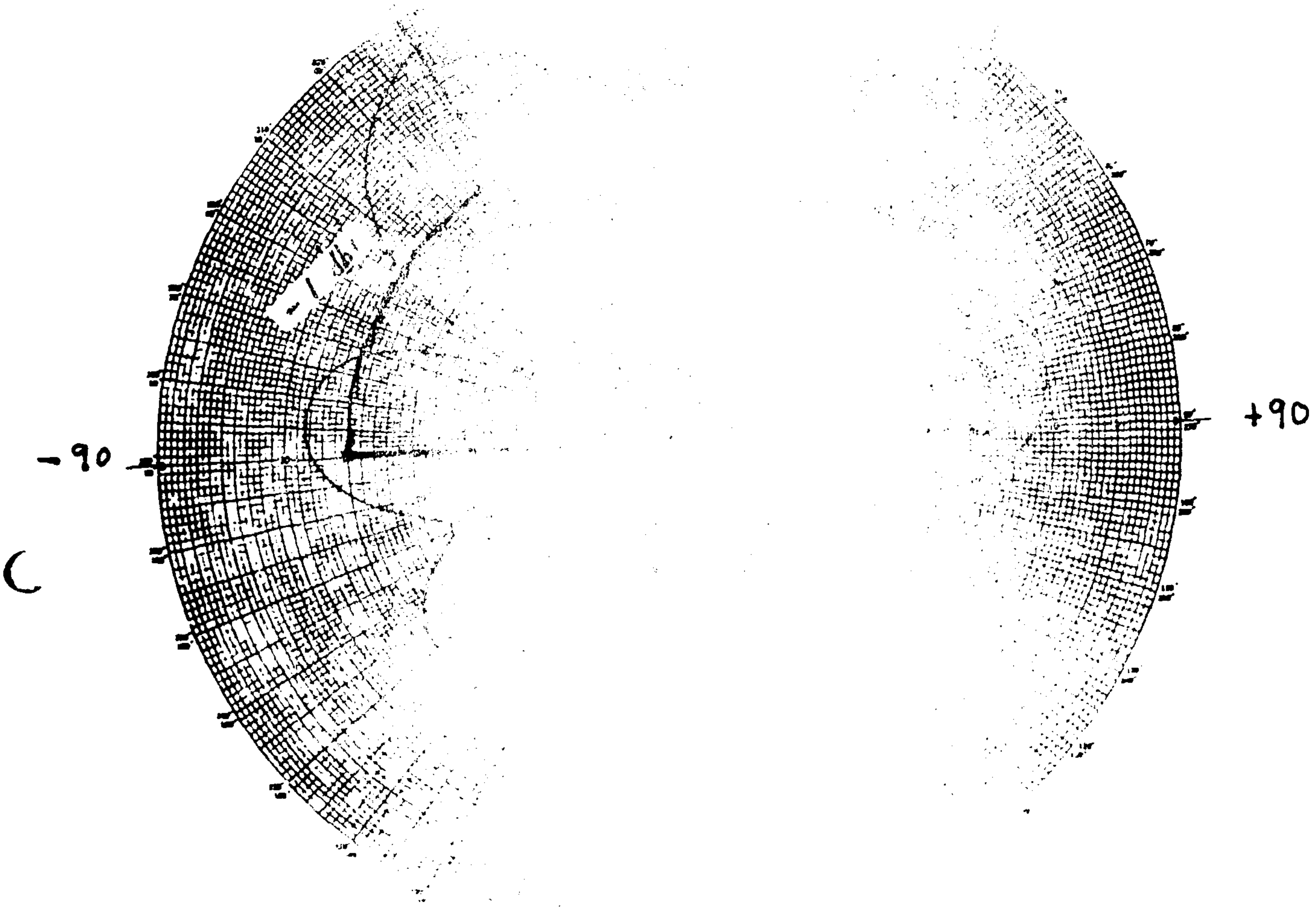
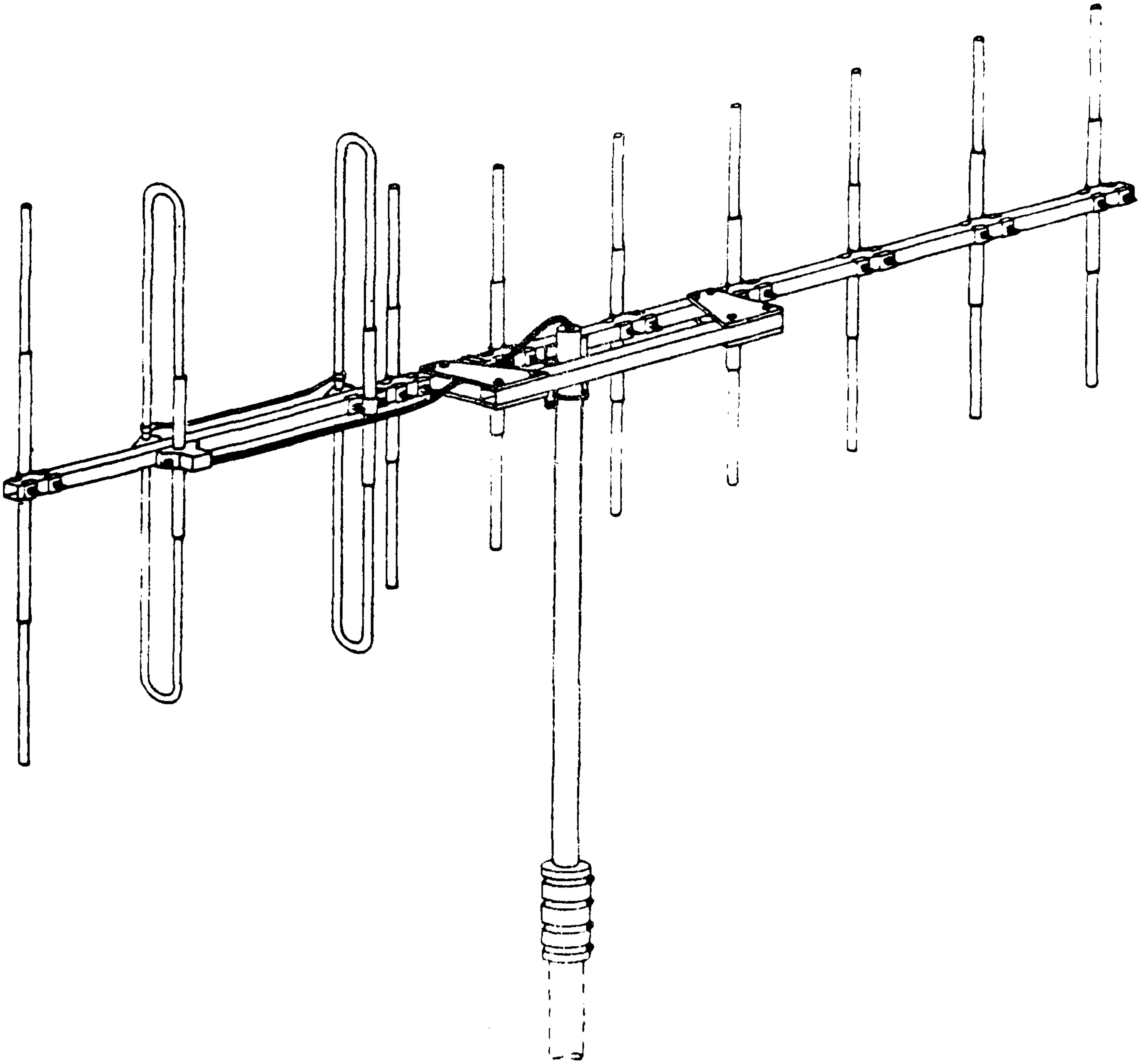


FIGURE [illegible] ERN

TACO
GENERAL INSTRUMENT CORPORATION
1 TACO ST SHERBURNE, N Y 13460 PHONE 607-574-2211

MODEL
Y102B-130V



TACO
GENERAL INSTRUMENT CORPORATION
1 TACO ST SHERBURNE N Y 13460 PHONE 607 [illegible]

MODEL D-2261A-1 OMNIDIRECTIONAL VHF ANTENNA

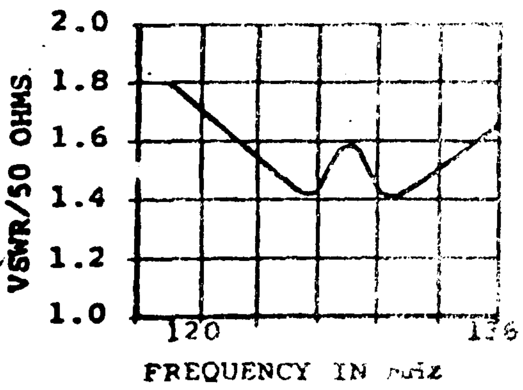
GENERAL DESCRIPTION

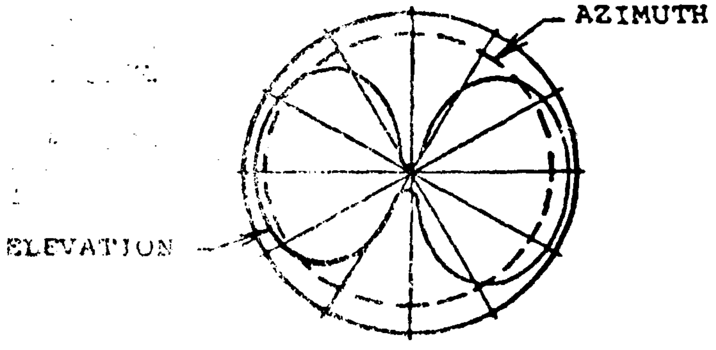
The TACO Model D-2261A-1 is a dual element vertically polarized omnidirectional antenna. Both elements have been combined in phase into a single input to provide a moderate gain of 4 dbi over the DOT/FAA frequency band of 118-136 MHz. Elements are enclosed in a completely sealed 2.250 in. (5.72 cm) diameter fiberglass radome, ultimately resulting in a lightweight, low profile, yet rugged communications antenna. The D-2261A-1 is supplied with a clamping arrangement which allows the user at his option to mount to a 1.25 in. (3.175 cm) or a 2.50 in. (6.35 cm) IPS mast. The clamp provides "in line" mounting with the mast which allows "hookup" to the antenna with exposing the transmission line to the environment.

THEORY OF OPERATION

The process employed in the D-2261A-1 antenna incorporates the patented Muldipol(tm) concept. The utilization of this technique results in a unit which has excellent "broadband" halfwave dipole characteristics over the entire 118-136 MHz VHF frequencies. The desired "figure eight" radiation pattern is generally constant throughout the band. Through "broadband" suppression of extraneous currents upon the transmission line the undesirable "Clover Leaf" pattern is avoided. By design, the outer conductors of both halves of each dipole are at the same DC ground potential. A grounding lug is provided at the base of each antenna for supplemental grounding capability.

ELECTRICAL CHARACTERISTICS (TYPICAL)





RADIATION PATTERN

EN

DAT